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KENTUCKY
AGRICULTURAL EXPERIMENT STATION

OF THE

STATE UNIVERSITY

BULLETIN NO. 154

Blowing Stumps With Dynamite

LEXINGTON, KY.
June, 1911

Gift

Kentucky Agricultural Experiment Station

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KENTUCKY AGRICULTURAL EXPERIMENT STATION,
Lexington, Ky

BULLETIN NO. 154.

BLOWING STUMPS WITH DYNAMITE.

By George Roberts.

There are, in various parts of Kentucky, areas of considerable extent which are still "in the stumps." Clearings are made and the stumps are generally allowed to stand until they decay enough that they may be pulled out without any more powerful machinery than a handspike. Sometimes an attempt is made to burn them out, but this process is not satisfactory, as it is almost impossible to burn the green stumps, and quite a good deal of fuel must be piled around a dead stump to burn it to the ground. When burned to the ground, the roots still remain to interfere with cultivation.

The best of stump pulling machinery is unsatisfactory in that it takes a great deal of time and horse-power to remove stumps by its use.

The writer knows of no experimental data to show whether it pays to remove stumps instead of working around them until they rot down. However, everyone will agree that it is desirable to get rid of them, and most farmers who have a little cash on hand would be willing to spend a reasonable amount to accomplish their removal. It would be a difficult matter to calculate in dollars and cents the gain that would be made by having the land free from stumps. They prevent a proper rotation of crops when the ground is fresh and strong, the time when the rotation should begin, in order to properly keep up the fertility of the soil. A field in the stumps is usually kept in some cultivated crop, generally corn, until the stumps have rotted down. By this time the soil has lost much of its virgin fertility, and it takes a long period to restore it to its original condition. Many such fields are never restored

554016

to a state of profitable production. Especially is this true in the more mountainous sections of the State.

If any attempt is made to rotate crops, and hay and small grain crops are grown, seeding and harvesting machinery cannot be used without large loss of space around the stumps. There is hardly any doubt that a reasonable expenditure of time and money in removing the stumps would pay. The saving of the patience and good disposition of the farmer is worth something.

However, the object of this bulletin is not so much to advise the removing of stumps as it is to give some exact and detailed information on the use of dynamite in blowing stumps.

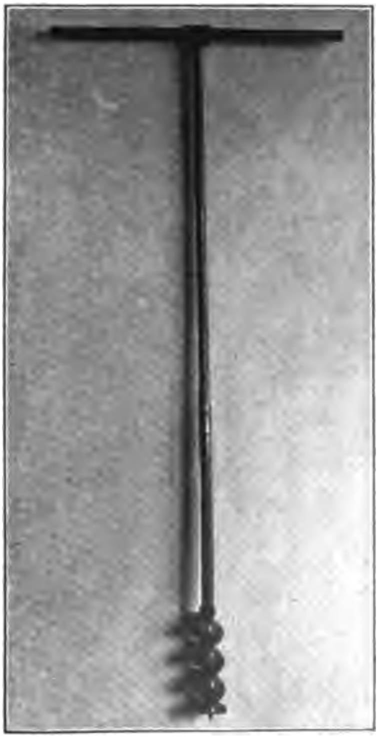
Two different lots of stumps were blown by the Experiment Station in the spring of 1911. One lot consisted of 102 stumps on the soil experiment field at London, Ky. The other lot was made up of 16 scattered stumps on the Experiment Station farm at Lexington.

Before giving the detailed statement of the size and kind of stumps and the cost of blowing them, it may be well to give some directions for doing the work.

In the first place one cannot be too careful in handling the dynamite and the caps used to set it off. Yet if good judgment is used it may be handled with safety. It should be stored in a dry, well ventilated place, where the temperature will not rise above 90 degrees F. The caps should be kept in a separate place, as they are much easier set off than the dynamite. It is unnecessary to tell most persons that dynamite should be protected from heavy jars, and should not be stored where any shooting is likely to be done. Some years ago a carload of dynamite was exploded at Jellico, Tenn., by a boy firing into the car with a 22 calibre rifle.

Most dynamite freezes at a temperature between 40 degrees and 50 degrees F. Some brands do not freeze above the freezing point of water. Frozen dynamite should not be used. Directions for thawing are generally sent out with each box of dynamite. Do not attempt to thaw it until printed directions have been obtained from the dealer. *Never undertake to thaw dynamite before a fire or in a stove.*

Directions for priming the dynamite cartridge may be obtained from the dealer as well as other directions one may need in handling it, and if he does not have such printed directions he may easily obtain them from the manufacturers. The object of this bulletin is not to give expert advice concerning explosives, for we do not wish to assume this responsibility when the manufacturers are in much better position to give directions. However, we will give the method employed in the blowing of the stumps by the Experiment Station.



About the only tools needed are an augur and a tamping rod. The augur is an ordinary two-inch wood augur with an extension welded on, making it about 3½ feet long. The end of the shank is threaded and a handle made by using a plumber's T and gas pipe. Put a pin through the T and the top of the augur shank to prevent it from screwing off when removing the augur from the hole. An old broom or hoe handle may be used for a tamping rod. Never use a metal rod.

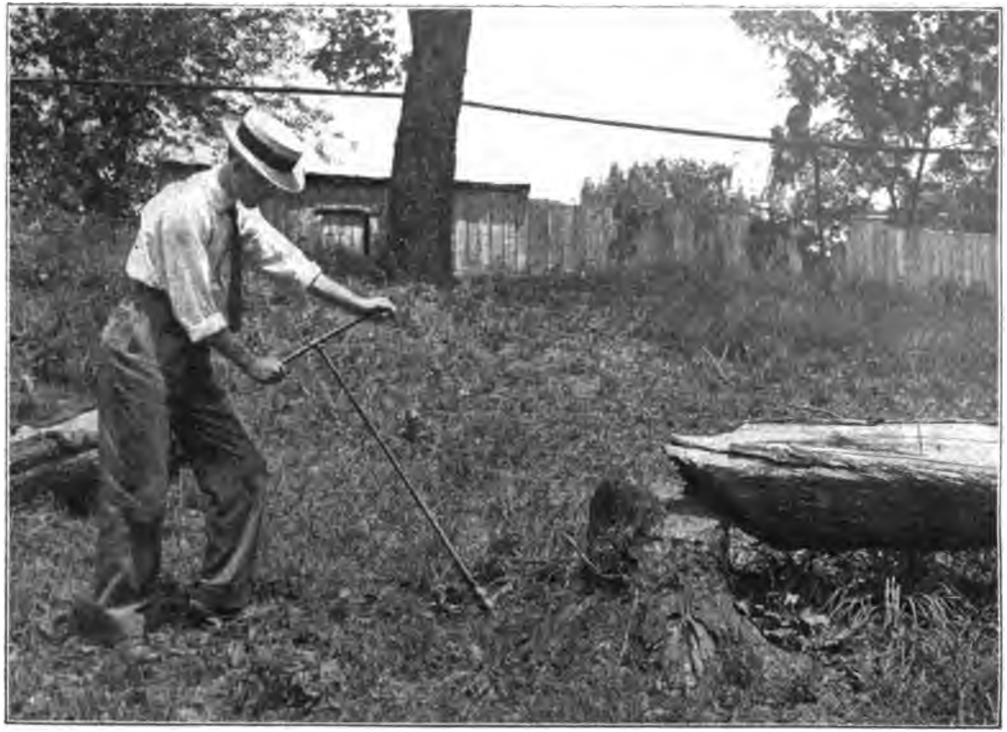
The hole is bored at an angle of about 45 degrees so that the charge will come under the center of the stump. When more than one cartridge is used, one-half of a cartridge is fitted with a cap and used as a primer. The remaining cartridges used in the charge are cut in halves and the wrapper removed. These are dropped into the hole one at a time and broken up and lightly pressed together with the rod. This concentrates the charge under the center of the stump. The primer is then put in, care being taken that it rests firmly on the charge. Then put in two or three inches of sand or fine dirt and tamp *lightly* so as to pack this on the charge. Then put in about 3 inches of moist clay and tamp a little more firmly. After 6 inches of tamping is on the charge, the remaining part of the hole may be tamped pretty firmly, but never use a hammer or any other object for driving the tamping rod.

If stumps are hollow, of course the charge will have to be located under some firm part of the stump. Some blasters throw a log chain tightly around the hollow stumps to facilitate their removal.

In blowing very large stumps the whole charge should not be placed in one hole. Holes may be bored from different sides and made to intersect under the center of the stump. Place the primer at the intersection of the holes and be sure that the other cartridges touch the primer.

Only a part of the charge necessary to remove a large stump may be used at first to slipt it. This partial charge is placed under the center of the stump. After the stump is split, the parts may be blown as separate stumps. We have found this successful with large green oak stumps.

The amount of dynamite to be used depends on several



Position of Augur in Boring Hole.

conditions, as the diameter of the stump; the character of the soil, and whether it is wet or dry; whether the stump is green or partly decayed, and the nature of the root system. It is therefore manifestly impossible to give directions as to the amount of dynamite to be used. The blaster will soon be able to judge. However, some idea as to the amount required may be gained by looking over the tables which are given below.

Fifty per cent. dynamite was used in most of this work. Forty per cent. was used on some of the dead stumps and was satisfactory.

If the person desiring the stumps blown is ignorant of the use of dynamite or is timid about the matter, he may employ some one who has had experience in the use of such explosives. If the employer wishes to relieve himself of liability for damage from accident to the operator, he should have a written agreement to this effect.

In the following table is given the number, size and kind of stumps removed from the London field, together with the amount of dynamite and labor required. This field contained about 6 acres and had been cleared about 8 years, long enough that small stumps of 10 inches and under could be broken out quite readily with an ax and grubbing hoe.

Stumps Blown at London, Ky.

No.	Kind of Stump	Diameter Inches	Sticks Dynamite Used
1	Dead Oak	12	2
2	Dead Oak	16	1½
3	Dead Oak	15	1½
4	Dead Pine	16	1½
5	Dead Oak	13	1½
6	Dead Oak	30	5½
7	Dead Oak	10	1½
8	Dead Oak	8	½
9	Dead Oak	12	1½
10	Dead Oak	13	2
11	Dead Oak	30	4½
12	Dead Oak	11	1½

No.	Kind of Stump	Diameter Inches	Sticks Dynamite Used
13	Dead Oak	18	3
14	Dead Oak	12	1½
15	Dead Oak	20	3½
16	Dead Oak	34	4½
17	Dead Oak	9	1½
18	Dead Pine	14	2
19	Green Oak	16	3
20	Dead Oak	14	2
21	Dead Oak	12	1½
22	Dead Oak	30	4½
23	Dead Oak	24	3
24	Dead Oak	30	1st shot 3½ 2nd shot 2
25	Dead Oak	38	5½
26	Dead Oak	20	3½
27	Dead Oak	24	3½
28	Green Oak	14	3
29	Green Oak	14	3
30	Dead Oak	12	1½
31	Dead Oak	22	4½
32	Dead Oak	27	4½
33	Dead Oak	15	2
34	Green Oak	14	4
35	Dead Oak	30	5
36	Dead Oak	14	2½
37	Dead Oak	11	1½
38	Dead Oak	14	2½
39	Dead Oak	30	6
40	Dead Oak	18	3½
41	Dead Snag*	20	4½
42	Dead Oak	8	1

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*More dynamite is required to blow a tree or snag than to blow a stump of same diameter, because of greater weight to be lifted.

No.	Kind of Stump	Diameter Inches	Sticks Dynamite Used
43	Dead Oak	16	3
44	Dead Pine	16	2½
45	Dead Oak	27	5
46	Dead Oak	6	½
47	Dead Oak	8	1
48	Dead Oak	13	2½
49	Dead Oak	16	3½
50	Dead Oak	15	2½
51	Dead Oak	6	1
52	Dead Pine	10	1½
53	Dead Oak	15	3
54	Dead Oak	16	3
55	Dead Oak	24	5
56	Green Black Gum	16	5½
57	Dead Oak	18	2
58	Dead Oak	8	1
59	Dead Oak	16	2½
60	Dead Oak	13	1½
61	Dead Gum	24	1st shot 2
			2nd shot 2
62	Dead Oak	16	1½
63	Dead Oak	10	1½
64	Dead Oak	12	1½
65	Dead Oak	6	½
66	Dead Oak	8	1
67	Dead Oak	14	2
68	Dead Oak	16	2½
69	Dead Oak	12	1
70	Dead Pine	10	1
71	Green Sugar Maple	16	5½
72	Dead Oak	12	2½
73	Dead Oak	12	2
74	Dead Oak	28	1st shot 4
			2nd shot 3
75	Dead Oak	12	1½

No.	Kind of Stump	Diameter Inches	Sticks Dynamite Used
76	Dead Oak	26	2
77	Dead Oak	18	2
78	Dead Oak	8	1
79	Dead Oak	16	2½
80	Dead Oak	15	2
81	Dead Oak	17	2½
82	Dead Oak	16	2½
83	Dead Oak	13	2
84	Dead Oak	10	1
85	Dead Oak	12	2
86	Dead Oak	16	2½
87	Dead Oak	12	2
88	Dead Oak	14	2½
89	Dead Oak	8	1
90	Dead Oak	14	2½
91	Dead Oak	16	2
92	Dead Oak	12	1½
93	Green Oak	8	2
94	Dead Oak	16	2
95	Dead Oak	12	1½
96	Green Gum	15	3½
97	Dead Oak	15	2½
98	Dead Oak	16	3
99	Dead Oak	24	5
100	Dead Oak	18	3
101	Dead Oak	15	3
102	Dead Oak	16	2½

Average diameter of stumps, 16 inches.
Total number of sticks of dynamite required, 265.
Average number of sticks required per stump, 2.6.
Time required for one man, 5 days.
Average time required per stump, 30 minutes.

Cost of 265 sticks of dynamite at 9c per stick*, $23.85.
Caps and fuse, $2.35.
Total cost of materials, $26.20.
Average cost of material per stump, 25.7 cents.
Cost of labor, 5 days at $1.50, $7.50.
Total cost of blowing 102 stumps, $33.70.
Average total cost per stump, 33 cents.

Stumps Blown on Experiment Station Farm, Lexington, Ky.

No.	Kind of Stump	Diameter Inches	Sticks Dynamite Used
1	Green Hackberry	20	5
2	Green Hackberry	10	5
3	Green Hackberry	7	6
4	Dead Hackberry	11	4
5	Green Elm	5	3
6	Dead Walnut	12	2
7	Dead Walnut	14	1½
8	Green Cherry	10	2½
9	Green Maple	12	1½
10	Dead Osage Orange	7	2
11	Dead Osage Orange	15	2½
12	Dead Osage Orange	13	2
13	Dead Osage Orange	11	2½
14	Green Oak	45	21
15	Green Oak	48	25
16	Green Oak	43	24

It will be seen by referring to the foregoing table that it is considerably more expensive to blow green stumps than dead ones. While the lot is a miscellaneous one, and contains kinds of stumps that are not generally found on farms, it brings out plainly the fact that green stumps require a great deal more dynamite than dead ones. Also a great deal more labor is required because much time is consumed in cutting the green roots, both before and after the explosion.

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*Note: In some small places dealers charge more than 9 cents per stick (18 cents per pound) for dynamite, but it could be bought at this price in Lexington when the stumps were blown.

The average diameter of the 9 green stumps in the table is 22 inches; the number of sticks of dynamite required was 93; the time consumed in blowing them was 18½ hours for two men whose wages were $2.75 per day; the fuse and caps cost 60 cents. Thus the total cost of blowing the stumps was $14.06, or $1.56 per stump. The cost of blowing the three large green oak stumps was: Dynamite, caps and fuse $6.70, and labor $3.85, a total of $10.55, or $3.52 per stump of average diameter of 45 inches. While these figures seem high, yet there is no other method by which they could be removed so cheaply.

The amount of dynamite required to blow stumps of the same kind in the same soil does not vary directly with the diameter, but more nearly with the square of the diameter, or, in other words, with the area of a cross section of the stump. The area of the cross section of a stump 48 inches in diameter is 16 times as great as the area of a cross section of a stump 12 inches in diameter. However, only judgment developed by experience can determine how much of the explosive shall be used in a given case.

The cost of blowing green stumps is from two and one-half to three times as great as for dead ones. While each individual will have to determine for himself whether he can afford the cost of removing the stumps, it may not be out of place to offer some suggestions.

Land would have to yield very high profits to pay for blowing green stumps. For ordinary land it seems to us that the most feasible plan is to plant it to some cultivated crop for say two years, during which the weeds and sprouts will be kept down. Sow to grass then, and pasture it for three or four years. Sheep are very effective in keeping down weeds and sprouts. What the animals do not keep down should be kept down with the hoe. When the small stumps are rotten enough to remove with grubbing hoe and ax, the larger ones may be blown at a cost that will not be prohibitive. One point seems clear, and that is, that when stumps are to be removed, the cheapest methods is by the use of dynamite.

Stump Before Blowing.

Explosion.

J. W. Dickson.

BULLETIN No. 216 NOVEMBER, 1911

THE UNIVERSITY OF WISCONSIN AGRICULTURAL EXPERIMENT STATION

Blasting with explosives is an effective and inexpensive method of removing stumps where care is used in placing the charge to secure its maximum effect. The operation is not dangerous, when properly managed.

THE USE OF EXPLOSIVES IN CLEARING LAND

BY

J. F. KADONSKY

COOPERATIVE INVESTIGATIONS BETWEEN U. S. DEPARTMENT OF AGRICULTURE, MINNESOTA NORTHEAST EXPERIMENT FARM, AND WISCONSIN AGRICULTURAL EXPERIMENT STATION.

MADISON, WISCONSIN

DIGEST

THE USE OF EXPLOSIVES IN CLEARING LAND

Use of Explosives to Pull Stumps involves little capital, few and simple tools, and requires no experience. Judgment as to proper amount and proper placing of the charge, will develop with careful observation. Dynamite and virite are the commonest explosives used on stumps.

Pages 3 to 6

The Charge Should Be Placed in the soil under the stump at the center of resistance which is not necessarily under the center of the stump. On a hillside, the center of resistance is toward the higher ground from the center of the stump. Where there are more roots on one side than the other, it is partially under them If the soil on one side is heavier than on the other, the charge should be placed toward the heavy soil.

Pages 7 and 10

Deep Charges Are Unnecessary, but the explosive should be placed just deep enough to avoid blowing off the top of the stump leaving roots above the plow line. If too deep in sandy soil, the gases escape without loosening the stump; in clay much force is wasted in raising dirt. This force is lost to the stump.

Pages 12 and 13

The Most Economical Results are obtained by placing the explosive in bulk form. As dynamite comes in cartridges of smaller diameter than the hole bored for blasting, a good way to handle it is to slit the paper wrappers three or four times lengthwise before dropping into the hole. The cartridge remains intact until it reaches the bottom of the hole, when it may be tamped into bulk form with the ram rod. Bulk virite is poured into place through a long tin funnel and must not be tamped at all.

Pages 6 and 13–15

Caps Should Be Inserted into the last part of the charge and pressed lightly. They are very sensitive and must be handled carefully.

Pages 6 and 15

Clay Soil Requires Different Explosive Than Sand Virite, or low percent dynamite exerting slow propelling force are needed here to avoid compacting the subsoil or leaving a large hole. High percent, or quick-acting dynamite, is needed in sand, to avoid escape of the force through the soil before it has done its work.

Pages 16 and 17

Electric Blasting Machines and electric caps are the safest, most expeditious, and often the most effective means of firing charges. A number of stumps can be fired simultaneously, the force from one helping the next one. If there is a misfire, it is safe to investigate at once.

Page 18

Misfires Are Due to the presence of foreign material in the cap, pulling the fuse out of the cap, pulling the cap out of the powder, or to a defective fuse. Powder fuses sometimes burn very slowly, causing an explosion when the operator is investigating.

Pages 18 and 19

Boulders Are Raised out of the ground by placing a slow charge where a pry would be placed for the same purpose. They are broken to pieces by exploding a high-percent dynamite in a crevice, or depression, or even on the surface.

Page 19

EXPLANATORY NOTE

One of the most important questions in connection with the development of Upper Wisconsin is that of removing the pine stumps which are left as a waste product in the process of lumbering. The problem is much simplified in the case of hardwood timber, as these stumps decay sufficiently in the course of a few years, to permit their ready removal. With reference, however, to the pine stumps, the presence of resins prevents decay to a large extent, and it is therefore necessary to resort to special measures to clear the land of these incumbrances. For this purpose, at present, explosives are largely employed, but unquestionably in the near future, power machinery will be utilized in such a way as to be of great service in the process of land clearing. Very recently, too, a method of burning, known as the charpit system, has been applied with success to this problem in the Pacific Northwest.

The magnitude of this work of stump removal may be recognized when it is considered that as yet but from one-half to five per cent of the area of many of our northern counties is now under cultivation. The problem is pressing not only in the forested region of this state, but is equally important in northern Minnesota and Michigan.

The studies here outlined have been confined to but one aspect of the problem, viz., the use of explosives, and represent work which has been undertaken cooperatively between this Station, the Office of Farm Management of the United States Department of Agriculture, and the Northeast Experiment Farm of the University of Minnesota.

H. L. RUSSELL,
Director.

THE USE OF EXPLOSIVES IN CLEARING LAND

J. F. KADONSKY.

Explosives are used extensively in clearing new land in Wisconsin and Minnesota, especially in the regions with clay soils once heavily timbered with pine. Explosives are now handled in many different ways, and there is great necessity of systematizing and describing the best method of clearing land with explosives. These explosives are used to extract stumps by breaking them to pieces and also to remove boulders. Explosives may also play an important part in splitting and jarring off the soil from the roots in connection with mechanical power in pulling stumps.

The advantage of using explosives in clearing new land is that a big investment is not necessary as in case of stump machinery. Explosives can be used in some way by almost every settler. The stumps and boulders are left in such form as to be handled easily and disposed of. The roots are freed from soil and the large parts broken up so they can be used for fuel, as is the practice in many sections at present.

An explosion is the sudden transformation of a solid into a gas which occupies a greater space. A common error is made by many practical men in thinking that the action of dynamite is downward, rather than being equal in all directions. It appears to act downward from the shattering effect on the soil or boulder, but the action upward is just as great only there is usually nothing visible to show it. The action on the soil chemically is not detrimental, as is commonly believed, but would rather tend to improve fertility.

KINDS OF EXPLOSIVES

Two common kinds of explosives used in Wisconsin and Minnesota are dynamite and virite. The dynamite ranges from 20 per cent to 60 per cent in strength, but the most universally used is 40 per cent. The 60 per cent "straight" acts very rapidly with a shattering effect, while the 25 per cent "extra" acts comparatively slowly with a propelling force. Virite is only of one strength equal to 40 per cent dynamite, as determined in the field, but much slower in action. The higher the strength the speedier and more sensitive the dynamite. Those grades marked "extra" are slower in action and should be used where a propelling force is desired.

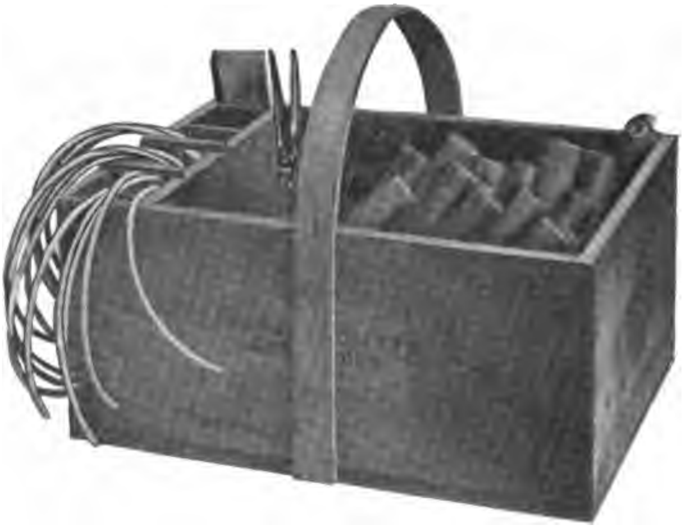

Figure 1. A handy box for carrying explosives, fuses and caps. Compartments in one end provide for the caps and fuses.

It is very important to have the different grades of dynamite where shattering and propelling forces are required. In raising a boulder or a stump, a slow propelling force is best, but for breaking rocks or stumps a speedy shattering force is necessary. Dynamite freezes easily and when in that condition should be handled very carefully. When it is left in the hot sun during the summer it is rendered much more sensitive and requires more precautions in working with it. The effects of the odor or contact with dynamite causes many operators to become sick. If a pair of canvas gloves is used in handling the cartridges they can be discarded when they become saturated. Breathing the smoke or fumes should be entirely avoided.

Virite is comparatively more stable than dynamite. The latter can almost always be exploded by a ball from a rifle, while the virite would remain intact. Virite is put up in bulk or cartridge form and is non-freezing and consequently can be used in the coldest climate without thawing. It has no odor which affects the operator as in case of dynamite, but the powder cannot be used in water unless confined in water-proof cartridges.

HANDLING EXPLOSIVES

Following is the equipment needed for blasting in the field: a supply box, auger, crowbar, shovel, wooden ramrod, and a cap-crimper. A supply box can be made on the farm by taking an empty dynamite box and placing a vertical partition across one end, leaving a space the width of an explosive cap box. At one end of this make a compartment that will just admit a box of caps. The remainder of this space can be divided equally by one-half inch cross pieces and each section *labelled 18 inches, 20 inches, and 24 inches,* respectively. The remainder of the box is used for explosives. Care should always be taken to keep the caps separated from the explosive. A wooden hoop may be nailed over this box for a handle so that it balances when filled with supplies. (See Figure 1.)

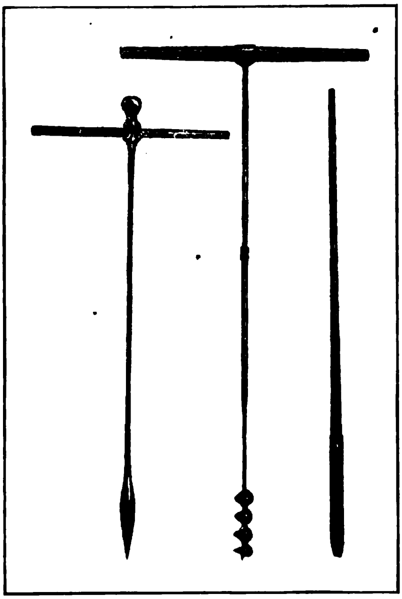

Figure 2. Three essential tools for preparing holes under stumps for blasting; large soil auger in the center, a crowbar at the right and a pick at the left for opening a hole under the stump. Each is an important labor-saving device in placing explosives properly.

A convenient auger is made by welding a long shank onto an ordinary two inch auger. Where the roots are not too numerous and admit a larger auger, it would be advisable to use it.. A medium-sized tapering crowbar should be used The large end should be drawn to an edge, and the other end, to a blunt point. The ramrod can be made from an ordinary broom handle and should be at least 3½ feet long. These tools are shown in Figure 2. A round pointed shovel is best for removing the soil from the roots when loading and in filling the hole when tamping the charge. A long tin funnel should be used to pour the virite, when in bulk, under the stump.

For making holes in the dynamite to receive the cap, a tapering hardwood stick just a trifle smaller than the diameter of the cap can be used. Attach this stick to a cord fastened to a trousers' button where it will not be lost. Where the stumps are of uniform diameter it is well to prepare the fuse of certain lengths before going into the field. Cut the fuse with a hand ax by laying it on a block on which a board is nailed horizontally and marked the desired lengths.

We also carry with us a roll of fuse which are cut in the field to meet exceptional cases. There are a good many different ways of handling this fuse. Some people blast with only about six inch fuse no matter how long the hole is, by lighting the short fuse and dropping the dynamite on the rest of the charge, exploding without tamping. I do not approve of this method.

The end of the fuse should be cut square, not on a slant. If cut slantwise, the point, becoming dry and hard, is likely to explode the cap when inserted into it; or this point is likely to turn over in the cap and cause a misfire. The fuses are then inserted into the caps and crimped with a crimper. Care should be taken that each cap is free from any foreign matter, since this will serve as a protection to the fire from the fuse and cause a misfire. The fuse should not be inserted into the cap too far and should never touch the bottom since this is very sensitive and may cause an explosion. When the end of the fuse enters the cap and is crimped so that it just holds and withstands a reasonable amount of pulling during the process of tamping the charge, it is sufficient. The fulminate in the cap is so sensitive that it is exploded by the fire from the fuse when the end is nearly one inch outside the opening of the cap, if the fuse be directed into it. Do not expect the fuse to burn like a fire cracker fuse. It is lit as soon as it gives a little spit of fire in answer to the match, but the outside cover of the fuse does not burn. Always retreat at least one hundred feet, after lighting the fuse, until the charge explodes. Instances have been brought to my attention where the fuse was lit in the morning and hung fire all forenoon and exploded about 11 o'clock.

PLACING THE CHARGE

In blasting a stump the explosive is always placed under it in the soil and not in the wood of the stump. To get to the desired point it is necessary to make a hole with an auger or crowbar between the roots into the ground at the proper angle to get the charge in the center of resistance. The hole should be made, if possible, between two prominent extending roots which come close together as shown in Figure 3. There are two reasons for this. First, there is less chance for the force to blow out of the hole, due to the resistance offered by these roots. Second, owing to the root distribution, there are generally no roots immediately behind these and consequently less chance to meet with obstacles in making the hole.

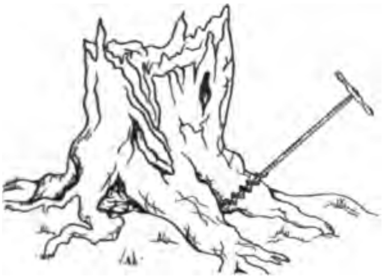

Figure 3. Charges of explosives should be placed under stumps, at the center of resistance. Using a long handled soil auger, the hole may be bored between two large roots into the soil, under the center of the stump until the center of resistance is reached.

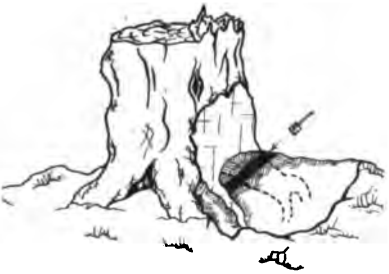

Figure 4. When a small root stops the progress of the auger, a small piece of dynamite with fuse attached, dropped down into the hole against this root and exploded, will remove it effectively and make it easier to complete the boring of the hole.

When a hole is started and the tool used meets with an obstacle in the form of a small root or stone such a resistance can often be removed by blasting. A piece of dynamite one inch long is used and in the side of the paper wrapper two cuts at right angles are made into which a capped fuse about four inches long is inserted. This charge (shown in Figure 4) which resembles a fire cracker to some extent, is then lit and dropped down into the hole next to the obstruction, without tamping.

The force of this small explosion generally renders conditions such that the process of boring can be continued. This charge, costing only a couple of cents, often saves an hour's work and also enables the charge to be placed where the maximum force will be received from the explosive. When the root formation is such that it is very difficult to get a large tool under the stump, a hole often can be made by driving the small end of the crow bar down so that the point terminates where the charge should be placed. Then take a small piece of dynamite about one and one-half inches long, crumble it up and drop it to the bottom of this hole. Try to get all or as much as possible of the powder to the bottom. A small stick can be used some times to get it down. Next take a capped fuse about four inches long, drop it down upon this powder and light. (See Figure 5.) When properly carried out this explosion will make a pocket under the stump which will admit the desired charge. Should the passage be too small or curved so as not to allow free passage of a cartridge, it should be crumbled and the contents poured down.

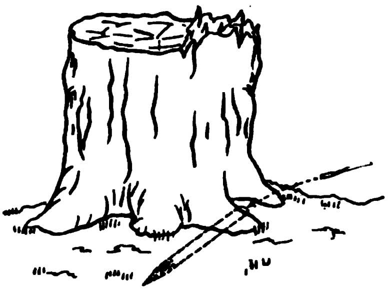

Figure 5. When the soil is very hard under the stump and boring difficult, break up a cartridge and pour the loose powder into the hole, as shown above. Then with a cap attached to a fuse set off this small charge to open the way for the placing of a larger charge.

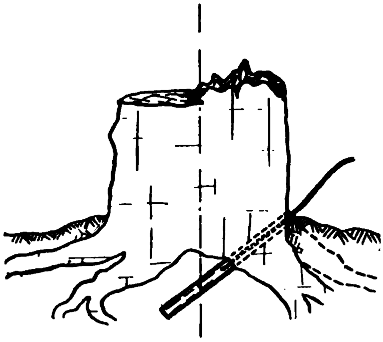

Figure 6. The hole should be bored past the center of the stump sufficiently to allow the explosive to be placed across this center as above, rather than on one side of it, as shown in Figure 7.

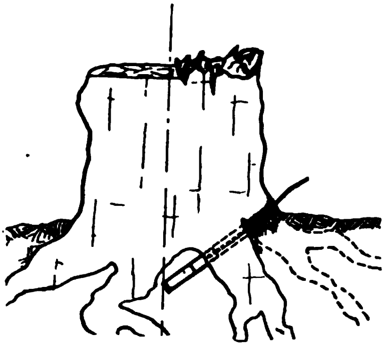

Figure 7. A common error in placing explosives is to bore the hole just to the center of the stump and not beyond it. When the charge is placed at one side of the center, it either merely blows off a part of the stump or forces away the soil at one side and does not remove the stump perfectly.

For an extremely large stump a big charge is necessary, placed in as compact form as possible. To do this a pocket is blown at the bottom of the hole in the same manner as above in the case of removing an obstacle. Care should be taken not to get the pocket too large so the dynamite cannot be tightly packed, which is absolutely necessary, in order to get the best results. On the contrary, virite must have plenty of room and must not be tamped under any circumstances. Where the dynamite cartridges are packed in the hole without breaking, leaving the explosive in a cylindrical form, the hole should be bored past the center of resistance, equal to half the length of the charge, which brings the bulk in the center of resistance as shown in Figure 6.

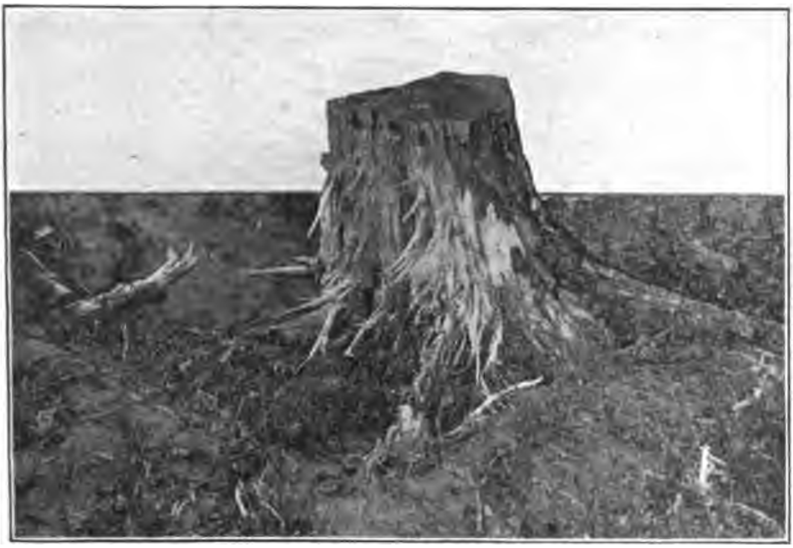

Figure 8. The charge was not properly centered under this stump, consequently the explosion removed one side and a part of the roots, leaving the rest of the stump in bad shape for further blasting.

The common way of placing the charge is to bore a hole under the stump at an angle of 45 degrees, terminating it at the center of the stump, as shown in Figure 7. When the cartridges are pressed down unbroken, the charge is then out of the center of resistance, and consequently, the results are not satisfactory.

Often when boring a hole an obstacle is met with before reaching the center of resistance, the operator places the charge, increasing the amount of powder believing this will do the work as well as when properly placed. This, however, is not the case. The side of the stump is blown away, cutting the roots, leaving almost all of them and half of the stump behind, as shown in Figure 8. It is necessary to emphasize this point. Place the charge far enough under the stump, in the center of resistance, but not always necessarily under center of the stump. Time is well spent in putting forth extra effort in doing so.

When a stump is located on a slope the center of resistance and the center of the stump are not the same; hence, when the charge is placed under the center of the stump, only part of it is blown out. Here the resistance is greater toward the higher slope, and consequently, the charge must pass the center of the stump to get it in the center of resistance as shown in Figure 9.

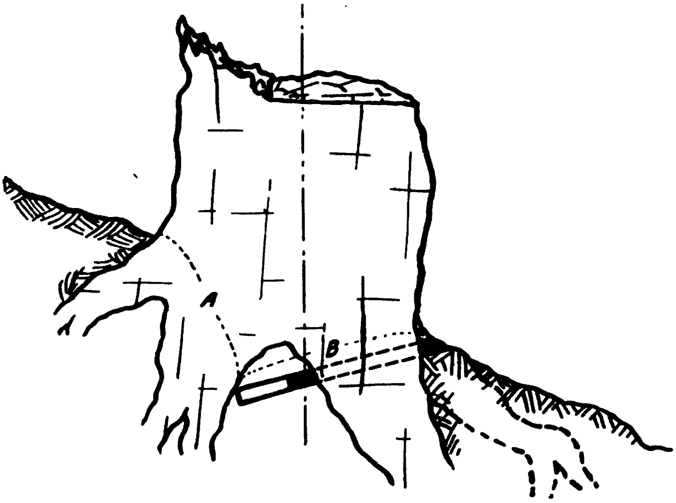

Figure 9. When stumps stand upon a hill side, the center of resistance is up-hill from the center of the stump. The distances, A and B, should be about equal so that the charge will not blow out of the lower side of the stump.

Often the root formation is greater on one side than on the other and when the charge is placed under the center of the stump the force takes the path of the least resistance, shooting out at one side. (See Figure 10.) To remedy this, place the charge over toward this heavy root formation, as in Figure 11, which will bring it in the center of resistance and give better results. Some times the nature of the soil on one side of the stump is such that it offers more resistance than that on the other, which must also be taken into consideration when blasting.

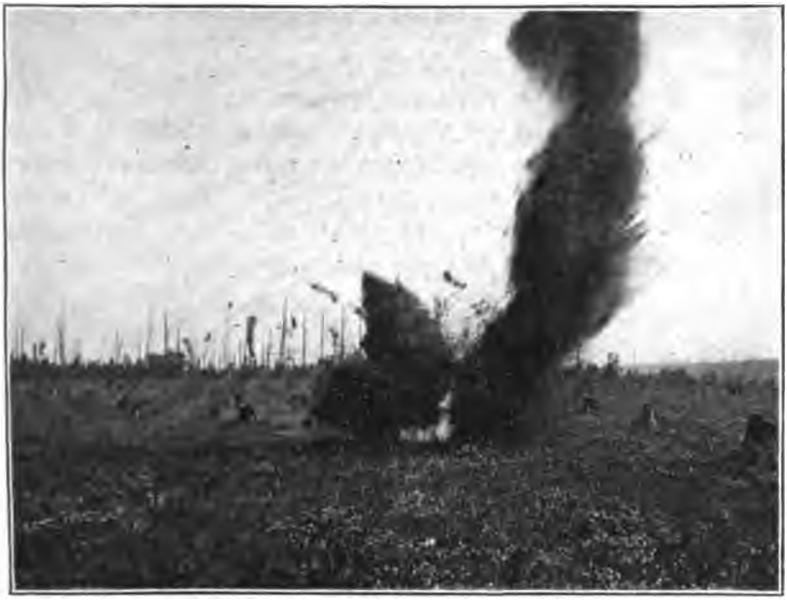

Figure 10. An explosion of a charge improperly placed at one side of the center of the stump. Note that the main force of the explosion is going out to one side.

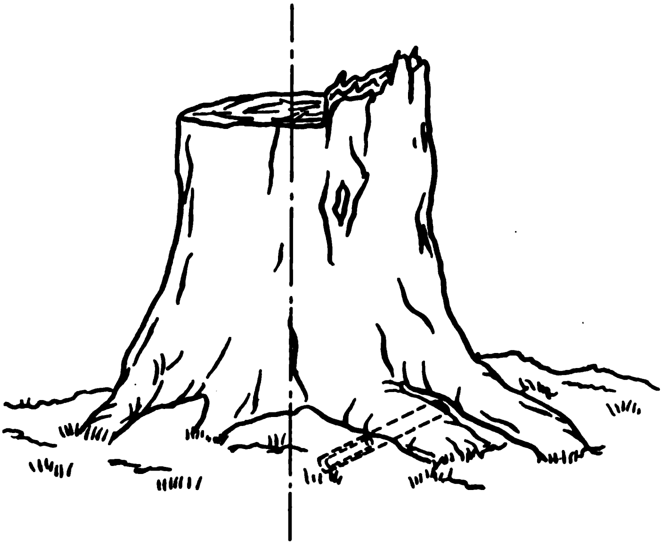

Figure 11. When a stump has unusually large roots on one side a charge of explosive should be placed upon the side of the center of the stump toward these roots.

DEEP CHARGES UNNECESSARY

The depth at which the charge should be placed is also very important and on this point varied opinions are held by different operators. It has been found by placing a charge at a comparatively great depth, as advocated by many, that it required a greater amount of explosive and the results obtained were not so satisfactory as when less powder was used at less depth. The cost was greater, the stump was not broken up and freed from soil, and larger holes were left to be filled, when the charge was placed deep. This is due to the fact that by placing the charge some distance in the soil below the base of the stump, a large mass of soil must be raised, which also serves as a protection to the stump. When an ordinary charge is deeply placed in a clay soil, the result is a pear shaped hole in the soil and a split stump through which the gases escape like the one in Figure 12.

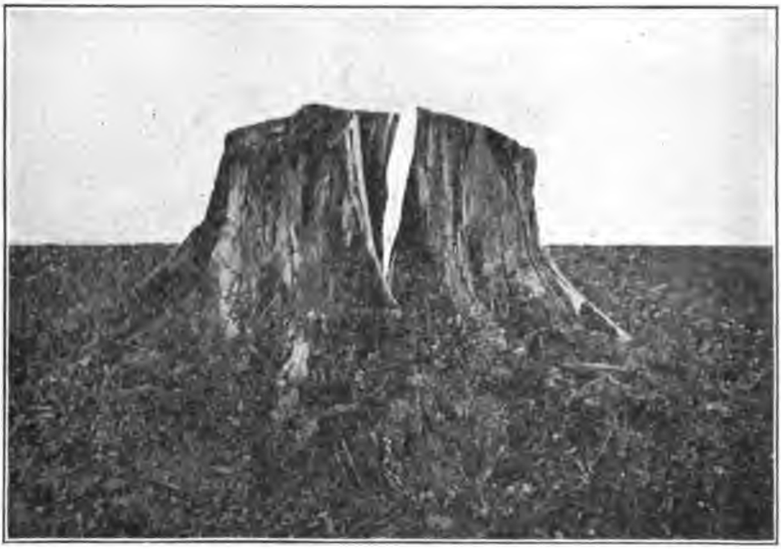

Figure 12. When a charge is placed too deep in clay soil below the stump the result is that the stump is merely split, as shown here. In sand, the soil is merely blown away, as shown in Figure 13. While the charge should be in the soil under the stump, it should be as close to the wood as it can be placed.

In light sandy soil the gases tend to blow out on either side of the stump between the roots when the charge is deep, leaving the stump in place as in Figure 13. This is due to the greater ease with which the force can escape at some distance below the base of the stump where there is a greater spread of roots than farther above.

Care should also be taken not to place the explosive too shallow. If the charge is not deep enough and the head of the stump is weak the result is that the top of the stump is blown off, cutting and leaving the roots above the plow line like those in Figure 14.

It is difficult to set any hard and fast rules regarding the depth at which the charge should be placed under the stump. The operator must use his judgment in each individual case, but place the explosive as shallow as possible, avoiding cutting off any part of the stump above the plow line. This will give the best and most economical results. As a rule it is best to place the explosive in a bulk form breaking up the cartridges, especially when blasting large stumps. The force then radiates equally from one central point and splits the stump into the maximum number of parts. When the charge is in a cylindrical form, most of the force acts at right angles to it and generally splits the stump into two parts.

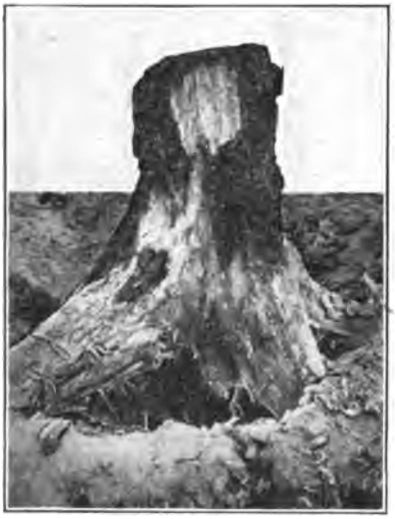

Figure 13. When a charge is placed too deep in light sandy soil, the force of the explosive blows away the soil and leaves the stump standing as shown here.

HINTS ON PLACING CHARGES

There are a few things that should be observed about loading to save time and get the best results. When the hole for the charge is large, it is well to take the powder out of the cartridge and tamp it well into a bulk form. The paper wrappers should also be included, since these, which are saturated with nitro-glycerin, are also explosive. The quickest and a most satisfactory way is to cut the wrapper lengthwise into four parts with a sharp knife as shown in Figure 15.

When this cut cartridge reaches the bottom of the hole and is pressed with the ramrod it bulges and crumbles into a mass. When placed in a cylindrical hole, the cut parts bulge so as to fill the opening completely, thus making the charge compact, which is desirable. (See Figure 16.)

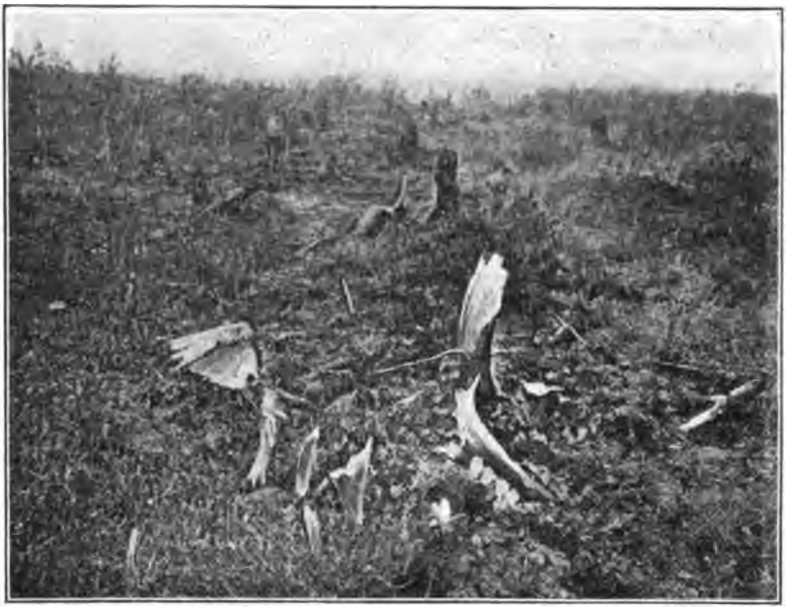

Figure 14. When a stump has a weak top and the charge is placed too shallow, the result of the explosion is that the head of the stump is blown away, as shown here, leaving the large roots above the plow line in a position very hard to remove.

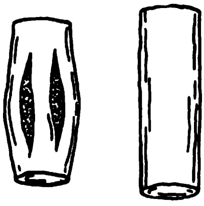

Figure 15. Slitting the wrapper enables the charge to be pressed compactly in the hole.

Into the last part of the charge, the fuse with cap crimped onto the end, should be placed. If an ordinary fuse is used, a very quick and satisfactory way is to hold the cartridge in the left hand and make a hole with a pointed stick slightly smaller than the diameter of the cap in the side near one end at an angle of 30 degrees. The cap is then pressed into it so that it is buried in the powder and the fuse bent back to form a sort of hook with the cap as a point. (See Figure 17) This is passed down the hole to the remainder of the charge and the fuse can stand a reasonable amount of pulling without coming out, but rather tends to go farther into the cartridge. The cap on an electric fuse can be inserted in the same manner, but the wires should be looped around the cartridge.

Care should be exercised not to tamp the part with the cap, but to press it gently. The other part of the charge must be tamped well if dynamite is used, but with virite, it must always be left in an absolutely loose form. The charge is generally tamped with soil, which is brought up with the tool in boring the hole, or with any loose soil which may be at hand. Always use a wooden ramrod in placing and tamping the explosives, *and never place any metallic tool down the hole near the charge under any circumstance.*

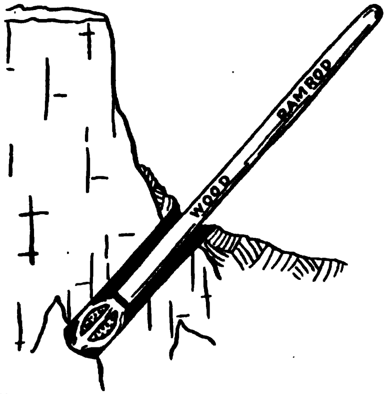

Figure 16. When pressing the cartridge into the hole, always use a wooden ramrod, never a metal crowbar, and press the cartridge hard enough to make it compact. The explosion will then be complete and effective.

When the operator has had some experience and knows the approximate amount of explosive required for a stump, it is well to load a large number and fire them at one time. This saves time and miles of travel if one blasts all day and fires each one after loading. A good way is to load for half a day and fire them during the noon and evening hour, when the rest of the workmen are not present.

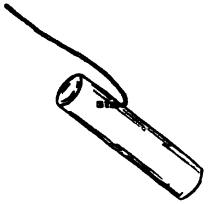

Figure 17. The capped end of the fuse is inserted hook-fashion into upper end of cartridge.

RELATION OF EXPLOSIVE TO SUB-SOIL

Each kind of soil requires a particular kind of explosive. It has been found that in the clay soils a slow propelling force is the most satisfactory, which is furnished in dynamite of 27 to 30 per cent strength. This explosive, acting slowly, removes the roots without snapping them off above the plow line, leaving the soil in a comparatively loose condition as shown in Figure 18, which is very important from a physical standpoint. When a speedy powder is used, as 60 per cent strength, on the clay soil, it snaps many of the roots, leaving them above the plow line and packing the soil firmly, leaving a sort of basin like that shown in Figure 19.

For the light sandy soil where the footing is not good and there is chance for the gases to escape, a speedy force should be used, equal to 60 per cent dynamite. The condition of the soil with respect to moisture regulates to a great extent the amount of explosive required per stump. Owing to a great variation in the structure of stumps, and soil conditions, it is impossible to give any definite information as to the amount of powder necessary to blast a stump of a given size. This must be regulated by the experience of the operator. Extremely loud reports and the throwing of the parts of the stump great distances is an indication of an excessive use of explosives. A deadened report following the explosion, the splitting and lifting of the stump just out of the ground shows the most economical use of the explosive.

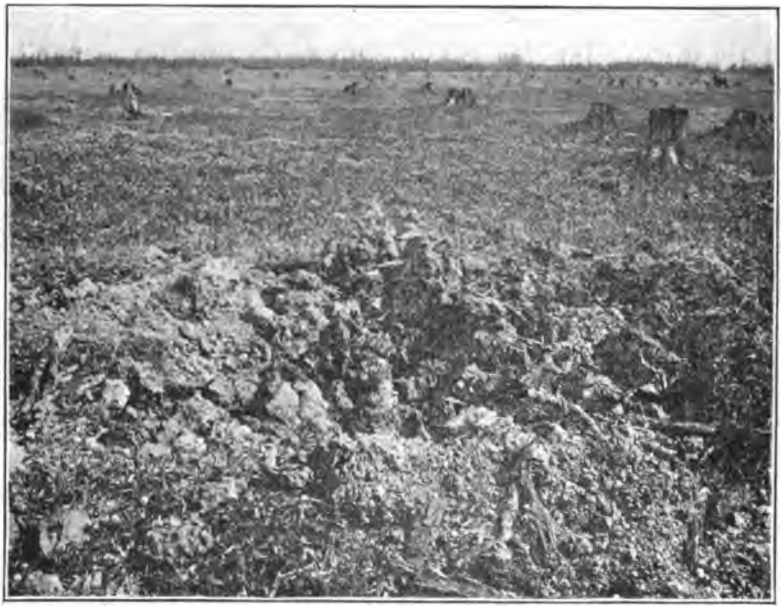

Figure 18. A dynamite of moderate strength, about 27 per cent, will leave the clay soil in a loose crumbly condition, as shown here, which is desirable rather than compacting it too much, as shown in Figure 19.

METHODS OF FIRING CHARGES

The most common way is to split the end of the fuse to expose the powder which is lit with a match. Some place a pinch of dynamite on the end of the fuse. The quickest and most satisfactory way when matches are used is to thrust the head of a safety match whose chemical part is just starting to burn into the end of the fuse. This never fails to fire, no matter how much the wind blows. It is well to scratch the match on an adjacent root or the sole of the shoe, so the head of the match cannot burn long before being thrust into the fuse, which is very important in this method. Where a large number of stumps are to be fired at once, a live brand or an iron rod one inch thick and about three feet long, heated in a burning rubbish pile in the field, is recommended.

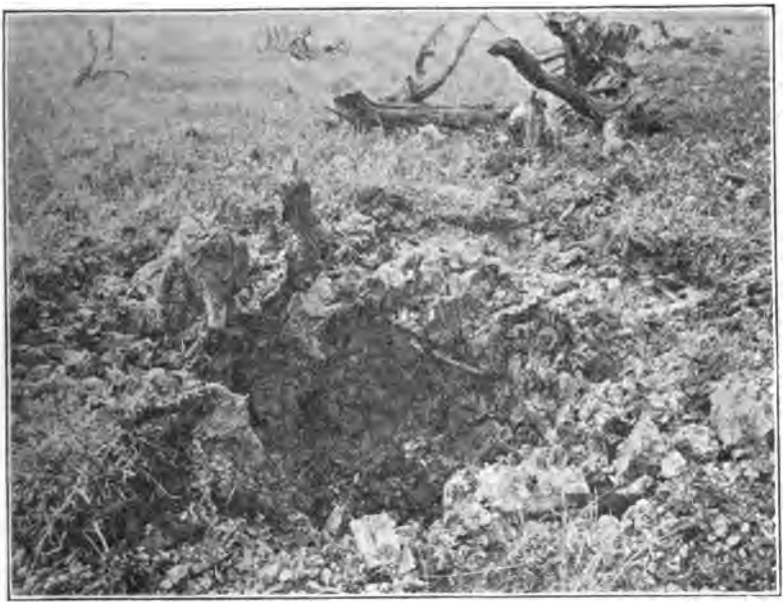

Figure 19. The effect of a charge of 60 per cent dynamite on red clay is to pack the soil solidly and to leave a large basin, which must be filled and levelled before the land can be plowed.

The safest and perhaps the best means of firing is to use an electric blasting machine for that purpose. An electric blasting machine consists of several electric dry batteries arranged in a box for convenience in carrying, and connected with a switch which must be closed in order to fire the charge. It is fitted with screw binding posts for convenience in connecting the machine into the circuit with the powder. A number of stumps close together can be fired simultaneously. The cap of the electric fuse is placed in the cartridge in the same way as the cap on the time fuse only the wire is looped about the cartridge. The wires running to the cap should be long enough so that they will project out of the hole when the charge is tamped.

Connect one of the cap-wires to a long wire running to the machine, two hundred feet away. Connect the other cap-wire to an insulated wire running to the next stump and so on through all convenient charges back to the blasting machine to complete the circuit. The method is illustrated in Figure 20. The charges are fired by closing the switch.

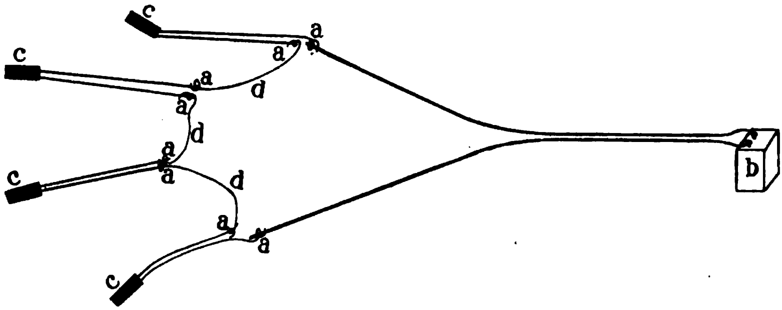

Figure 20. Method of blasting several stumps at once; b represents electric blasting machine; c, a charge at a stump connected by the cap-wire into the circuit at a; d represents an insulated wire connecting one charge with another.

Care should always be taken to have the wires disconnected at the battery while preparing the charges. Electric firing has advantages over time fuse in that accidents are less likely to occur, the chance for misfires is reduced, and there is a saving of time by blasting a number of stumps simultaneously. Often two or more adjacent charges must be fired at once to get the best results, which is possible only by the use of electricity.

CAUSES OF MISFIRES

Misfires are due principally to the presence of foreign material in the cap; pulling the fuse out of the cap; pulling the cap out of the powder; or to a defective fuse. Perhaps the most serious accidents occur when a time fuse burns to a certain point and then owing to some defect, burns very slowly for a few minutes. The operator after waiting for what he considers a long time, approaches the stump, when the explosion takes place, with serious results to himself.

A misfire should be left until one is absolutely positive that it will not explode. Do not go near it until the following day. Then it can be treated by making a hole or removing the tamping toward the charge carefully, but not coming in contact with it. A small charge is then placed near the first, which, upon exploding, generally sets off the first charge.

BLASTING BOULDERS

In blasting boulders, the aim is to throw them above the surface and break them into smaller parts so that they can be handled easily. For raising these masses, a slow propelling force should be used. The charge should be placed under one end of the boulder at a point where a pry would be placed if it were to be raised in this manner. A pocket for this charge can be made under the rock by means of a long handled pointed shovel. The explosive should come in contact with the boulder and have a flat ground surface parallel to the rock surface with which it is in contact, to work against. To break a rock on the surface, a very speedy explosive as 60 per cent dynamite is most satisfactory. It can be placed on the mass and covered with wet soil. The most effective way is to get the charge into a crevice or a hole in the surface of the boulder if possible.

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Agricultural Experiment Station

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The Use *of* Explosives *for* Agricultural and Other Purposes

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How weeds and briars grow up about a boulder in a field. In this case the stone itself is not very large, but the total land area put out of business is three times as much as the stone covers.

INTRODUCTORY

THIS bulletin is published by the Institute of Makers of Explosives. The aim is to give the united conclusions and the sum of the experience to date of nearly all makers of explosives and of farmers who have dealt successfully with the problem of the uses of explosives on the farm.

The material has been classified and assembled so any phase of it will be available easily and quickly. Uncertainties have been eliminated as much as possible in favor of known facts and formulas established by actual experience. It is offered as a manual or handbook for farmers, home and road builders, contractors, park makers and others who must remove rocks and stumps from land, and as a textbook for students of agriculture.

Readers will find that the recommendations are impartial, and that the suggestions on that part of the work which can be done best with explosives are particularly complete.

Boulders and Ledges of Rock

Eight generations of farmers have picked stones off the fields of a great many farms in this country, and in these same fields all the boulders too big to be moved by the direct strength of men and horses still are dodged by the present farmers. Some land cleared and farmed as long ago as the Revolutionary War has not had the "niggerheads" removed to this day.

Those stones that project above the surface of the ground can be avoided, but those hidden underneath are more serious trouble makers. The man who works his own land for years gets to know where they lie, and can escape them to a certain extent, but it is by broken plowshares that a new plowman learns their location.

In former years, before the value of land began to increase as it has of late years, farmers found more profit in locating a new acre that had fewer stones or none at all than in removing those from a stony acre. But that time is past. Farm land today can be made to pay without removing the boulders, but a far greater return can be had if they are removed. Stony farms can be sold, but not for big prices. Thoughtful farmers remove the rocks.

It is surprising how much there is to know about the disposal of boulders. Too often this work has been attempted in ways that were crude and wasteful of energy and time, and considering these items, very expensive. This is partly due to the lack of published data describing easier, simpler ways. The up-to-date farmer will not tolerate methods that are wasteful or unprofitable. He may find the information he wants in the following pages.

The Profit and Loss Account of Boulders

The interference of boulders and rock ledges with farming operations and profits takes many forms, and its cost can be estimated from a glance at a few of them.

This is the sort of perpetual tenant which pays no rent, and on which this bulletin declares war.

Time Lost

On ground where a cultivated crop is grown, each boulder causes the waste and loss of about half an hour per year of the time of a man with a team, worth five dollars a day. Four seasons' loss will remove the stones. They "eat their heads off" as the saying goes, ten or more times during the active lifetime of the average generation.

In addition, the breakage and damage to tools and machines may amount to as much in total loss as that from waste of time. This is particularly true of those farms where modern heavy implements are used, as, for instance, the heavy disc harrows for four or more horses, the gang plows, and all the tillage tools pulled by traction engines. Tractor plows and harrows are sure to be broken in stumpy or rocky land. It is impossible to make good time with gang plows or harrows among boulders, because of the constant stopping necessary, and besides, the work done is bound to be poor. Ten to twenty boulders to the acre are just about as bad as 100 for the man with the engine implements—they make good work and speedy work impossible.

Weed Breeding

About each rock that sticks above the surface some weeds are sure to grow. There never is the stone, or log, or stump, on or in the ground but where you can find a thistle or two, or several specimens of other equally noxious plants, growing close to the edge or out from under it. These single weeds re-seed entire fields.

Danger to Horse and Men

Another feature of the loss sometimes caused by tight stones in fields is the injury to horses and men caused by the sudden strain and jerks. Horses sprain leg joints, shoulders, hips and backs. Many spavins have their beginning in the ugly twists sustained. Brood mares often are caused to lose their foals prematurely. The baffling for which stones are responsible is one of the most common causes of balkiness of farm horses. A team can be ruined in a short time by such treatment.

The danger to men is not so common, but when it does come it comes heavily. The records of the past generation show that many a farmer was struck with a plow handle when the plow point encountered a stone that was tight. Sometimes the result is a broken arm or hip, or rib, or worse still, a rupture. The newspapers frequently report accidents caused by the driver of a mowing machine being thrown from the seat into the knives, or under the heels of the horses, when the machine suddenly struck tight obstructions such as stones.

The direct loss of crops which would grow on the land occupied by the boulders need not be stated in figures. Every farmer knows that the loss of corn, wheat, or hay on a square rod amounts to 15 to 50 cents a year.

Low Land Value and Increase

Tight stones on a farm are bound to keep its selling value down. One of the first things a shrewd buyer of land will want to know is whether the soil is free of rocks that interfere with cultivation. One of the easiest and surest ways of increasing the value of land, for selling, for actual use, and in the estimation of other people, is to clear away the boulders.

Value of Stones

The stones themselves may not be without value when they are broken up in pieces small enough to handle. It is well for every farm to have a pile in some convenient place, where they can be had any time they are wanted. They are valuable for building material, and in drains and walks. At the rates prevailing in many places it is easy to collect fifty dollars' worth of stone right near where it is needed and save both the cost of the stone and most of the expense of hauling.

Some of the more common purposes for which stones are valuable on farms are for blind drains, for lining ditches along roads or in fields, where the water gouges out the sides or bottom on account of a grade or turn, for road foundations, for repairs to walks, for constructing steps, chimneys, walls, etc., for filling in concrete construction, and for building garages, houses, barns and silos.

Clearing land of boulders should not be regarded as an expense, like taxes, or like the cost of shoes to wear. It is an investment, like the purchase of Government bonds, or like the purchase of shoes by a storekeeper, to sell again. When money is spent for removing boulders by a farmer, he is buying something—the clean land—that at once begins to pay back the cost of the work. It pays for itself within three or four years and then keeps right on paying dividends year after year.

Kinds of Rock and Their Nature

It helps if you know your rock when you go to break it up, for many different kinds exist as boulders and ledges on farms and in roads. In some sections the term "hardhead" is used to describe one kind of boulder. Another term is "niggerhead." It is better to know the rocks by the names which designate their real nature.

Rock Qualities

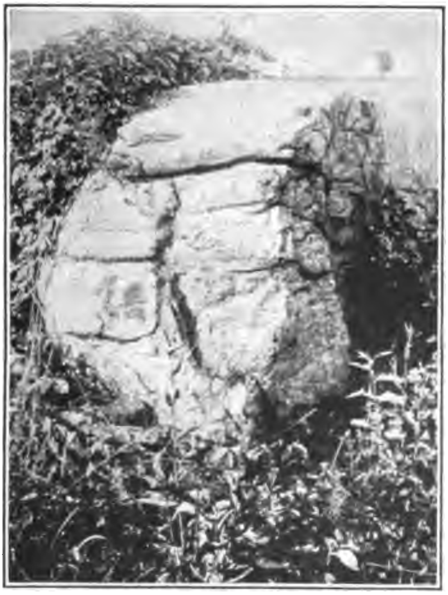
What does make a difference is that some stones are easy to break and others are not. To understand why, a study of the stones is necessary. Their resistance depends on their comparative hardness and toughness. These two qualities must not be confused, for they are not the same.

Hardness and Toughness

To illustrate, window glass is hard, but not tough. It will scratch very hard steel, but will shatter under a light blow. Untempered iron is tough, but not hard. It can be ground away rapidly by a stone, or scratched with glass, but it is extremely difficult to break by pounding or twisting.

To some extent stones possess the same qualities, and in addition almost all of them have one or more lines of weakness. Most rocks have a grain, not unlike the grain of wood, and will split more easily along the grain, and less easily in any other direction. It is safe to say that all rocks have joints running in one direction, and some rocks have two sets of joints running at right angles. The joint lines may not be visible, but the force of a blast or of a sledge will find them. There is still another sort of weakness in rocks with which the blaster should be familiar. This is the bedding plane, or layer—with lines running at right angles to both joint-lines mentioned.

Some knowledge about the joints and natural cleavage planes makes the breaking of rocks easier. Even the most massive rocks are divided into blocks of varying sizes, making them split in some directions easier than in others. The cracks will tend to stop short and splinter out or to run entirely through the stones, depending on the toughness of the rock, while the blocks will or will not crumble much according to their hardness.



How the seam and joint lines crisscross in most stones. A little inspection of a stone nearly always will show a spot where the force can be applied to break it with much less force or greater effectiveness than if the stone is attacked at solid spots.

Description of Rocks

In these brief remarks we will make no attempt to give the geological classification of the rocks, but will try to identify the typical rocks found as boulders and ledges by names which are used most generally, and to make

Two fields which will cost $50 to $200 or more an acre to clear of stumps and stones. If the land can be used for residential purposes or for some form of intensive farming like trucking or fruit growing, it will pay to clear such places, but it will not pay to clear them for general farming and pasture purposes.

clear their nature. Common names for different kinds of rock or stone are not always satisfactory because the common name applied generally to one kind of rock in certain localities in numerous instances is applied to an entirely different kind of rock in other localities, but it is hoped that any confusion will be limited.

Talc, Gypsum and Shale

These three classes of rock seldom exist as boulders, though they sometimes interfere with cultivation in the form of ledges close to the surface of the ground. In this shape they nearly always are full of two sets of joints, and lie in thin beds. Sometimes the seams are so close together that the rock breaks up into blocks only an inch or two square. They are fairly tough, are inclined to crumble rather than split or crack, when struck with a sledge hammer, and are easy to drill.

Limestone

Usually takes the form of flat boulders on the surface in fields or of ledges which project almost to the surface or above the surface several feet. Limestone generally has two systems of joints. It also has bed lines wide apart—a foot or more. This kind of stone nearly always is tough, breaking off, rather than splitting far. Its hardness varies.

Slate

The boulders of this class frequently are nearly round. Slate rock is characterized by a thin shingle structure. The leaves are less than a quarter of an inch thick. There are joints as well. The stone is tough, breaking only a short distance (but splitting on cleavage lines easily), soft, and inclined to crumble.

Occurs as boulders of every shape and size, and as ledges of all sorts. The ledges usually are stratified—that is, in beds of a thickness of 1, 2, 3 or more

See picture on preceding page

Sandstone

feet. It has frequent joint lines running in two directions, and it breaks up into irregular sized blocks of more or less rectangular shape. The sand particles which compose the stone are very hard. When the cementing material is silica the stone is blue or white, and much harder than when of an iron origin, making a brown or red stone. For purposes of drilling, blue sandstone must be classified as a hard rock, and brown sandstone as softer rock; and for breaking purposes, both kinds may be listed as soft. It crumbles easily, and is rather tough.

Lava, Mica Rocks, Feldspar

These rocks and others like them in structure lie in layers from 2 to 100 feet thick. They have no other bed lines, but they have infrequent joint lines. Lava, excepting that of the pumice type, is hard and brittle. The boulders split fairly easily into pieces of irregular shape and size.

Conglomerate

A mixture of various rocks, such as slate, sandstone and the like, often in the form of pebbles cemented together, making a rock that lies in beds. It may be crystalline and very hard—even flinty—or it may be only medium hard. The boulders are rather brittle than tough. Joints in one direction are located wide apart. Boulders of conglomerate rock sometimes have a ball-like structure, with layer after layer 1 to 6 inches thick, and joints every 2 to 4 inches. The layers of such rock crack off like the skin of an onion.

Granite

Occurs often as boulders, though frequently there are granite ledges. Granite is of a massive structure, with frequent joints. It splits easily. It is hard to drill. Some granite breaks easily while other is difficult to shatter.

General Features

Some rocks are full of irregular cavities resembling bubbles, and these generally make the breaking easier. The cavities interfere with the regular joint lines and cause the splitting to take place along new lines of weakness.

The amount of force required to break a rock depends on its hardness and its relative toughness, and on the lines of weakness or cleavage which run through it. Hard rocks usually crumble less easily than soft rocks, but generally split better when once started. Tough rocks are hard to split into small pieces, while brittle ones shatter to bits under a proper blow.

The point at which the force should be applied for the most and quickest breakage depends on the structure of the rock and the direction and frequency of bedding and joint lines.

Methods of Clearing Away Rocks

Rocks too large to be pried out and loaded for hauling by hand, and tight ledges, must be broken. Following are described eight methods of breaking them. Each method has advantages under certain conditions, but some are much more serviceable, convenient and easy than others under most circumstances.

List of Methods

Eight Methods

Hauling: Consists of either dragging with chains or loading on sled or wagon. See page 31.

Sledging: Consists of hammering them into pieces small enough to handle. See page 14.

Burying: Needs no description. See page 14.

Plug and feather breaking: Intended for splitting out building stone. Consists of drilling a series of small holes in a line across a boulder, and then driving into these holes special steel wedges.

Blasting by drilling: Called "blockholing" when referring to boulders. See page 23.

Blasting by undermining or underdrilling: Called "undermine blasting" or "snakeholing." See page 19.

Blasting by mudcapping: Also called "doby shooting," "plastering" or "blistering." See page 15.

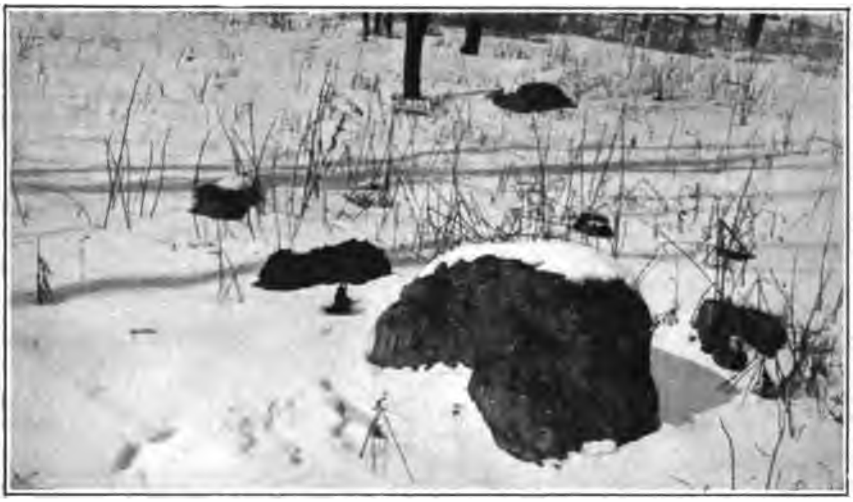
Choice of a Method

Cost, Men, Time and other Factors

In the practical handling of rock clearing, the elements to be considered are the costs of labor and material required. These are governed by the nature and amount of rock to be broken. Time is also an important factor.

The softer and more brittle boulders, if they are not large, may be disposed of by any of the above methods. Very hard and tough rock cannot be

How a boulder can mar the appearance of a farm from the roadside view. Such a stone leads possible buyers of a place to think that the field contains many such.



The disposal of this partly buried boulder called for rolling it out of its bed in the ground without breaking it, and then mudcapping it. It was rolled out with one cartridge from the position shown in the first picture, and (see next page).

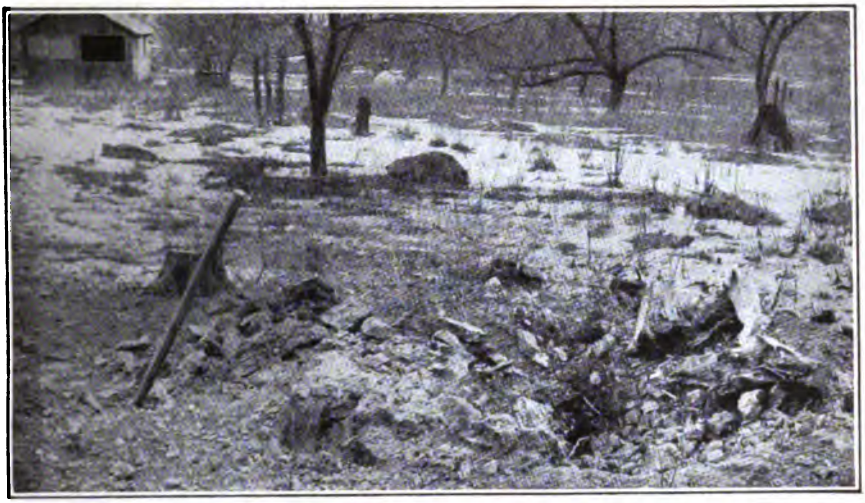
sledged into pieces successfully. When such rocks are to be blasted they should be drilled (blockholed) rather than mudcapped or undermined. Ledges of rock always should be broken up by blasting drilled holes. The limits of size of rock at which mudcapping becomes impracticable are explained on page 15.

Labor conditions are important. On some farms men are very scarce and wages are high. At other places there are periods when laborers are practically idle and can be put to disposing of stones, without much extra cost. In the former case it is wise to let explosives do all the work possible with no more drilling, sledging, handling and hauling than absolutely necessary. In the latter case the amount of explosives used should be kept down, and the idle men left to do the resulting extra work.

The time element is equally important. If nothing else demands the attention of the men on the farm, a slow method is all right, but when stones must be removed in a hurry, the quickest method probably is the cheapest in the end.

When the cost must be kept down as much as possible, and when easier and better methods are not available, burying and breaking by fire may be resorted to, provided there is labor available at little cost. Sledging, when practicable, is a cheap method if labor and time are not considered, provided good sledges are available. But it is slow, hard work. This applies to any way of disposing of rocks except blasting. If the conservation of energy as well as of time and men is desirable, the use of high explosives is the only method to consider.

Mudcapping is the easiest way to blast boulders in most instances, but takes the most explosive of the three blasting methods. It seldom should be attempted with boulders containing more than 5 cubic yards of stone unless they are thin slabs, and is expensive with trap rock or other very hard and tough material. Rocks should be flat rather than round, or at least should have a flat side on which the charge can be placed.



mudcapped a few days later with five cartridges with the result shown in the second picture. Note that the entire rock has been reduced to small fragments requiring no further handling.

Undermining or "snakeholing" has practically the same effect as mudcapping, though it requires less explosives and, usually, a little more work. Blockholing, though effective and economical, requires time and tools to drill the holes.

Mudcapping and undermining are pre-eminently the methods to use where there are only a few boulders to dispose of, since one man can do in an hour by these methods what it would take much longer to do by any other method. Stones that are deeply imbedded should be undermine blasted lightly to roll them out, or at least to loosen them, before they are mudcapped. Some very large stones should be both undermined and mudcapped, with two or more charges fired simultaneously with an electric blasting machine.

Other combinations of methods will suggest themselves to a resourceful blaster.

Study the rock. If it is imbedded, roll it out by undermine blasting as above directed, and examine it on all sides. Usually you will find that an undermined or mudcap blast, unless the charge of explosive has been small, will break up the boulder and make blockholing unnecessary.

Detailed Directions for Disposing of Boulders

Digging Out

Small boulders, weighing only 100 pounds or so, may be dug out and rolled into wagons on planks, or dragged off the field with chains. With larger stones, hauling is slow business, and is likely to result in injury to men. The hard straining required to lift the rocks, added to the danger from the falling of heavy stones, makes what would seem to be one of the simplest and safest of jobs an exceedingly hazardous one.

Sledging Rocks

A practicable method of disposing of rocks is to break them up with sledges. Use heavy sledges—the heavier the better. The tough rocks are almost impossible to break in this way. It is impractical to sledge up large rocks of any kind.

Pay particular attention to the direction of the grain and the lines of cleavage. A blow right at a vital point often will break a rock in two when you could hammer away an hour at another part without much effect.

When you sledge rock, there is much danger from flying bits of stone, and it is a good plan to wear gloves. Tie your coat sleeves over the gloves or the gloves over the sleeves, turn your collar up, wear a cap which pulls down over the ears, and wear goggles. If you have no goggles, be careful to shut your eyes when striking the rock.

Burying Rocks

One way is to dig a pit alongside the stone, and tip it over. This is suitable for stones that can be pried over. Large stones must be undermined and let sink down slowly. Let each end down separately. Extreme care must be used in this operation to prevent the rock from rolling on the man who digs. Burying heavy stones is a dangerous operation, and has crippled and killed many a man.

Burying rocks is open to the objection that at some time the work may have to be done over again, on account of not getting the top low enough. Frost, erosion, and other forces gradually have the effect of bringing the stones to the surface. If the rock is large, it will interfere seriously with the growth of anything planted over the spot. Buried stones are beyond your reach if needed for building purposes.

Blasting

The easiest way of breaking stones is to do it with high explosives. The directions for this work are here given in full detail, with careful attention to mudcapping, blockholing and undermining or "snakeholing," and to combinations of these.

Blasting Boulders and Ledges

All of the methods described in the preceding chapter are more or less useful, but in actual practice the disposal of boulders or ledges nearly always will be impractical unless you use explosives.

Mudcapping Rock

Briefly, mudcapping rocks consists in placing the explosive in a neat pile on a face of the rock, covering it with about 6 inches of stiff wet clay, and exploding it. When done right, the force of the explosion breaks the rock.

It is the enormous speed of the gases which accounts for the success of such a blast—the time element. Mudcap blasting is made possible by the intensely fast shattering action of some of the modern high explosives. It cannot be done satisfactorily with black powder nor with the slower kinds of high explosives.

Owing to the resistance of the air and the inertia of the material in the mudcap, the gases strike the rock like an enormous sledgehammer swung at a rate faster than the eye could follow. Such a blow, if in proportion to the size and strength of the stone, is sure to shatter it.

Description

Of the three distinct methods of blasting, mudcapping is the best one to use when the boulders to be broken are flat and brittle and smaller than 5 or 6 feet across.

Probably the most economical mudcapping per cubic yard of rock is in blasting sandstone boulders having flat sides, and containing 4 to 6 cubic yards. Some sandstone is brittle, yet hard to drill, therefore should be broken by mudcapping. Shale, slate, conglomerate and other such rocks break very successfully under mudcap blasts. Mudcapping is less satisfactory, owing to greater quantity of explosives required, when very hard and tough rocks such as trap, etc., are to be broken. In fact, mudcap blasting had better not be attempted on hard, tough rocks that are more than 3 feet in diameter unless no drills are to be had, and the stone must be removed immediately.

Preparing the Rock

If the stone lies free on the surface, it is ready for the placing of the explosive. If it is buried in the ground more than a foot, it is a good plan to dig or blast away the dirt before attempting the mudcap blast. One way to do this is to dig a trench round the stone, to within a few inches of its bottom. Another way is to place one or more small charges down alongside the stone and to loosen up the dirt or throw it away from the sides, but in such a way as to leave the ground firm and undisturbed underneath. A third, and probably the best way where the stone is almost buried, is to explode a slightly larger charge down under one side of the stone to roll it out of its bed, and onto the surface of the ground. Then it is ready for mudcapping.

Locating the Place for the Charge

In determining the best point at which to place the explosive, consideration of the principles of rock structure, as outlined on pages 7 and 9, should be the basis. Study the make-up of the rock and determine the directions in which it will split the easiest. Look for and work for the hair-thin but far reaching seams. Clean the dirt or dust from likely-looking places. The joint lines most of the time will be hardly visible, yet they are important if the most complete and economical breaking is to be secured.

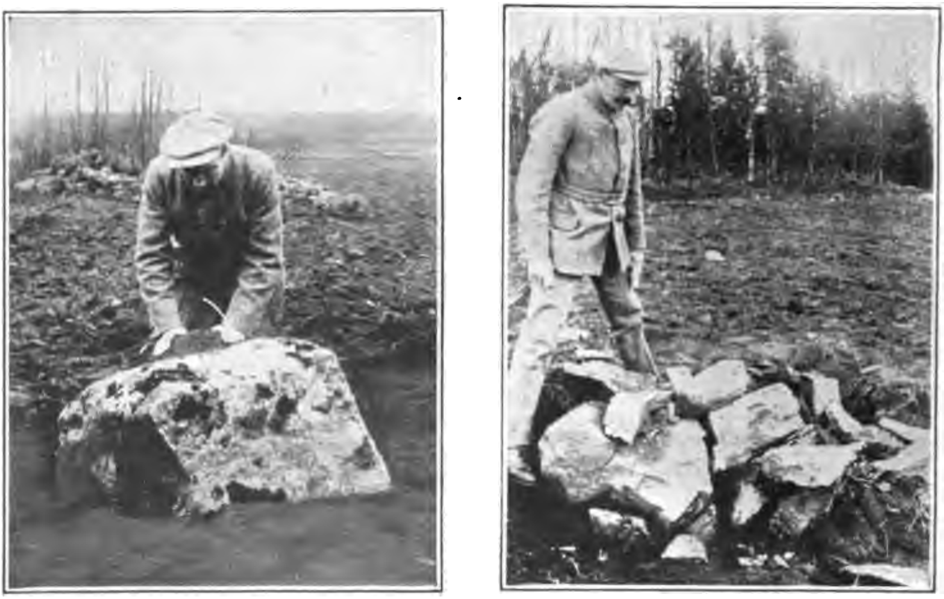
Some workers say that they put the explosive where they would hit the stone with a sledge if it would be possible to break it with one blow. The big thing is to get the explosive at a vulnerable point on the rock, whether this is top or sides. It may be necessary to support the explosive and its covering of mud with a banking of dirt, or with props from the ground, if the charge has to be located down along the side.

It is better to place the explosive in a depression or hollow on the stone, or at least on a flat face, than on a round or bulging surface. A round face acts to some degree as an arch, and resists the blow of the explosive much more than a flat face. A depression gives the explosive some confinement that enables it to do better work.

In placing the explosive it sometimes is well to deepen crevices or depressions with a drill or cold chisel, in this way making what might be called a semi-mudcap out of the blast. Such a blast is more efficient than when the explosive is placed on a flat or rounding surface. If it is desired to break the boulder or rock into pieces of certain shapes and sizes, make channels across the face with a chisel or mason's hammer and place the explosive in these channels. The process is like breaking ice by chopping channels across it. This treatment gives rough dimension pieces, but it may increase cost.

Putting the Charge in Place

The charge of explosive ordinarily should be placed in a low cone at the point selected on the rock. If less than four cartridges are to be used, it is well to take all the explosive, except ½ cartridge for priming, out of the paper wrapping and press it into place. If the charge is large, one or more of the cartridges can be left intact and bedded in loose explosive. Sometimes the cartridges bed-in better when cut in two. The explosive should not cover much area on the stone, since widely spread charges tend to distribute their force and have lower breaking ability. Sometimes it is a good plan to place the explosive



How a mudcap charge is pressed down on a flat side of a boulder, with fuse projecting from the mud, and how a boulder is broken up. This charge was placed properly and was of the right amount. Note that none of the pieces were thrown far, though the stone is well broken up.

in a long, narrow mass—if there is a long depression, or crack, or the rock is much longer than it is broad. Thin edges of the mass should be pressed in and made steep and square.

Inserting Cap

Before all of the charge is in place, put in the cap with fuse or the electric blasting cap. See pages 143 and 150. The best way is to prime a part of a cartridge of explosive in the usual way and bed this in the loose explosives. If you decide to do this, stand the primed powder on end, with fuse or wires projecting from the top, and the closed end of cap pointing toward the center of the whole charge and then press the rest of the loose explosive about it.

If a primer of this kind is not used, the cap must be inserted directly in the charge. To do this punch a hole a little larger round than the cap about one-third of the way down in the top of the charge. The cap should be in the upper third of the charge. To place the cap deep in the mass might lower the efficiency of the blast.

Use the handle of the cap crimper or a blunt-pointed stick for punching the hole, as directed on page 147, and see that the cap is pushed to the bottom of the hole and that the explosive is pressed closely around it.

The covering of mud should be put over the charge carefully. Be sure that the cap is not pulled out of the explosives during the covering operation, or later.

The Mud Covering

The mud cap should be, preferably, of stiff wet clay. If clay cannot be got conveniently, use the heaviest earth you can find. Sand is the least satisfactory material, but can be used if made thoroughly wet. In any case, the mud-cap must be MUD and not dust.

At least 6 inches of mud cover should be placed over the explosive. This means 6 inches of covering in all directions over all of the charge. If the charge is 6 inches broad, then the mudcap would cover at least 18 inches of the rock, with the charge centered under it. To make a mudcap when the surrounding ground is dry, it is a good plan to gather and mix the mud in an old dishpan or box. Then to apply it on the rock simply turn the pan or box over at the right place and press the mud down so that no possible air spaces remain between it and the explosive or the stone. Be careful that there are no stones in the mud covering. They fly like bullets when the charge is fired.

Amount of Explosive

The amount of explosive to use depends on the size and shape of rock and on its toughness and hardness. Below is a table which will serve to guide the blaster. These figures should be high enough to cover tough stones. Less explosive may be used for rocks that are easier to break. Rocks smaller than one cubic yard require more explosive than their size-proportion.

Approximate Number of Pounds of Explosives Required for Mudcapping per Cubic Yard of Rock

Sandstone, slate and similar soft or easily broken rock	1	lb.
Limestone and other intermediate rock	1¼	lbs.
Marble, trap, granite and similar hard tough rock	2	lbs.

While this table serves as a basis for calculating the amount of explosive required to break boulders, it is only approximate, as the weight of the charge does not continue to increase according to the number of cubic yards in the boulder. Some blasters may prefer the following table, which gives the approximate number of cartridges required for each diameter of stone.

Number of 1¼ x 8 Inch Cartridges of Explosive Required for Mudcapping Boulders of Different Sizes

	Sandstone slate and similar soft, more easily broken rock	Limestone and other intermediate rock	Marble, granite, trap and hard, tough rock
1½ ft. greatest dia.	1¼ cartridges	1½ cartridges	2½ cartridges
2 " " "	1½ "	2 "	3 "
2½ " " "	1¾ "	2½ "	3½ "
3 " " "	2 "	2½–3 "	4 "
4 " " "	4–5 "	5–7 "	
5 " " "	7–10 "		

Firing Charges

Charges in mudcap blasting may be fired by either fuse and caps or by the electric method. The advantages of each method are discussed on pages 159 to 164. The electric method is the only one that can be used when more than one charge is to be fired at the same time.

Kind and Grade of Explosive

The kind and grade of explosives best to use for mudcapping rocks is one having a very quick action of great shattering or disruptive power. The best explosive for this purpose is one of 40%, 50% or 60% strength. The straight nitroglycerin dynamites are a little quicker in action than the "extra" or ammonium nitrate explosives, and for mudcapping should be the first choice. See page 153. But the ammonium nitrate dynamites are equally powerful, when of equal percentage strength, and though they are slower in action, tending to break the rock into larger pieces than nitroglycerin explosives, their work is satisfactory for mudcapping.

When another explosive than those recommended above is on hand on account of some other use, it may be used for mudcapping with success, though its use may be more expensive. Almost any high explosive for farm, mine or quarry work, may be used in an emergency. Even the 20% high explosives that are best for soil blasting can be made to break rocks in this way, though their performance will not be very satisfactory. When these lower percentage explosives are used, particularly if of the ammonium nitrate type, the quantity must be increased greatly. The use of such explosives will result in cracking the stones into a few large pieces rather than into many fragments. Whenever there is much mudcapping to do it will pay to get the proper explosive. In cold weather, use only the low freezing grades of these explosives.

Tools

The only tools necessary for mudcapping are a shovel, a pocket-knife and cap crimper, though an old dishpan or similar receptacle and a water pail often can be used to advantage.

Cost and Time

Breaking average sandstone boulders by blasting by *the mudcap method* on some jobs has cost fifteen to twenty cents per cubic yard. Granite, limestone, marble and trap rock boulders have been broken for slightly more. Mudcapping costs per cubic yard of rock run up fast when the boulders are very large, say larger than 6 to 8 cubic yards each. Trap and other tough rocks are expensive to mudcap. The shape of the rocks has much to do with the cost and practicability of breaking them in this way.

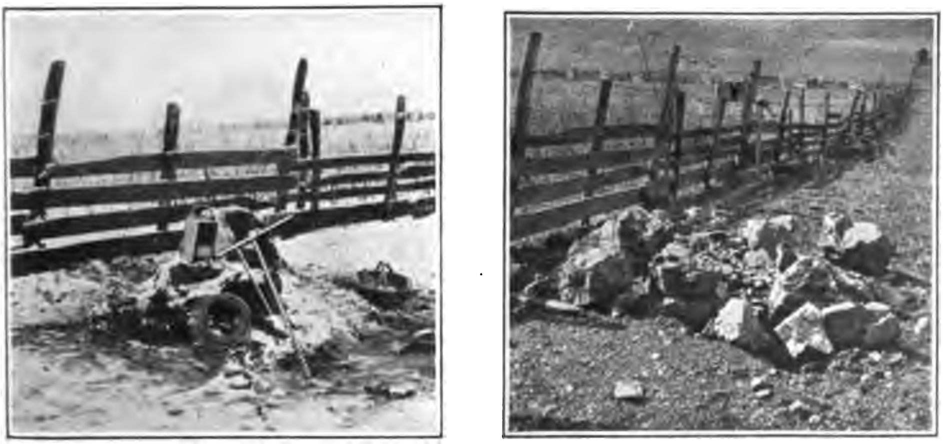
The approximate cost of mudcapping can be computed on the basis of the amount of dynamite required as given in table on page 17. The time required to mudcap rocks is very little. When wet ground for the mudcap is at hand, a man can have a stone lying round in pieces within 10 or 15 minutes after he gets on the ground. Many practiced blasters use no more than 5 minutes for each boulder.

Suggestions

Three feet of fuse burns about a minute and a half and under ordinary conditions is enough to permit the firer to reach a place of safety. If an electric blasting machine is used, the operator should stand at least 250 feet away, and should watch for and dodge any flying piece of rock coming in his direction. Avoid standing behind a shelter that may let stones through, as the branches of a tree. See page 164 for discussion of misfires.

A rock will often break better if it is jacked or pried from the ground and allowed to rest on small stones under the ends or corners. Sometimes odd shaped rocks, particularly if they are long, are broken better with two or more mudcap charges placed at different points and fired simultaneously by the electric method, than by one charge. Usually it will be best to locate such charges on opposite ends of the rock, though this rule is not good every time. Sometimes one may be a mudcap and the other a snakehole or undermine charge. Before proceeding with any mudcapping, read the chapter of this bulletin beginning on page 152, about the nature of explosives, detonation, tamping, freezing, thawing, etc.

The result to be expected from a successful mudcap blast is to break the stone into a great many pieces, none of them too large to handle. If a heavy blast is used on a small brittle stone, half or more of the stone may be almost powdered, and few or none of the pieces may be much larger than a man's fist.



Two pictures: How a proper undermine blast can be made to break a stone that is partly buried. Two charges of 50 per cent. ammonia explosive were used under this stone, and fired simultaneously, with the result shown.

Undermine or Snakehole Blasting

Description

To break a stone by the undermine blast method, the charge of explosive is placed against the under side or bottom of the stone with the solid ground as its backing. Less explosive is required than with a mudcap, since the confinement is better, owing to the earth backing and the weight of the stone.

This method is superior to mudcapping because less depends on the shape of the stone under the ground or the depth it is buried, which are always hard to determine with certainty.

Undermining or snakeholing works better when the stone to be broken has a flat side down, and with flat boulders rather than round ones.

To shatter a stone by this method, as by other methods, due attention must be given to the hardness, toughness and seams, as outlined on pages 17 and 19.

Locating the Holes

When a boulder is well buried the first thing to do is to probe about it with a sharp quarter-inch steel rod, to learn the shape of the under side and the condition of the ground. In any case, the charge of explosive should be placed as near as possible underneath the center of weight of the rock.

Making Holes

Holes for the explosive can be made with a crowbar and sledge or with a dirt auger. The crowbar likely will be the most serviceable. If the hole is not large enough to hold all the explosive required at the right point, you can make use of a scraper to enlarge the hole at the bottom. See page 61 for illustration. In blasting very large rocks, small tunnels can be shoveled out.

The practice of enlarging the bottom of the hole by "springing" with an inch or so of a cartridge of explosive, is seldom to be recommended in undermine blasts of stones, on account of possibly enlarging the cavity too much and forming cracks extending into the surrounding earth.

Placing the Charge

The explosive should be placed as nearly against the rock as possible. When the rock is undermined by digging, the explosive should be packed in a compact bulk, as in a mudcap charge. If you get the charge an inch or two away from the rock with dirt between, its breaking effect on the rock will be reduced. Read the directions for loading a hole, on page 28, and for placing a mudcap charge on a rock, page 16.

Inserting Cap

The cartridge of powder containing the blasting cap should be the last or next to the last to go in. The cap should not be against the rock, but if possible in the outside portion of the charge. The business end of the cap should be pointing directly toward the center of the charge.

The charge must be thoroughly and tightly tamped. If there is not good firm resistance all the way round it will blow the dirt out from under the rock without doing any stone breaking at all. It is a good plan sometimes to tamp the dirt the whole way round the stone before the charge is exploded. Never use a metal tamping rod in the hole or near the charge of explosive. It may strike sparks from the rock or from small pieces of stone, and cause a premature explosion.

Firing

Firing the charges may be done either by the cap and fuse method or with electric blasting caps and blasting machine. Each method has its advantages and adaptations to certain conditions as fully explained on pages 159 to 164. How to prepare charges, including the fixing of the fuse and cap, inserting and tying them in the cartridge of explosive and other details, are told on pages 142 and 151.

Amount of Explosive

The amount of explosive required to shatter rocks by the undermining method depends on the size, shape, toughness and hardness of the rock. The table here will serve as a guide. These figures should be high enough for average tough rock, but it must be remembered that the amount of explosive required does not always change according to the size of the rock to be blasted.

Approximate Number of Pounds of Explosives Required for Shattering Boulders "Snakehole" by Undermine Blasting, per Cubic Yard of Rock

Sandstone, slate and similar soft or more easily broken rock	¾ lb.
Limestone and other intermediate rock	1 lb.
Marble, granite, trap and similar hard, tough rock	1½ lbs.

Some blasters may prefer a table based on the diameter of the stones. Such a calculation can be used satisfactorily, but in this case, too, a great deal depends on the shape of the boulder.

Approximate Number of 1¼ by 8-inch Cartridges of Explosive Required to Shatter Boulders of Different Sizes by Undermine Blast

	Sandstone	Limestone and other tough rocks	Marble, granite, trap and similar very hard, tough rock
1½ ft. greatest dia.	1 cartridge	1¼ cartridges	2 cartridges
2 " " "	1¼ "	1½ "	2½ "
2½ " " "	1½ "	1¼ "	3 "
3 " " "	1¼ "	2 "	3½ "
4 " " "	3-4 "	4-6 "	
5 " " "	6-7		

If larger sizes are to be broken, better calculate the amount of explosives required by the cubic yard basis. Your figures will be more accurate. When rocks are to be rolled out without shattering, comparatively small charges can be used. The following table will give an idea of the amount of explosive necessary.

Approximate Quantity of Explosive Required to Roll Out Buried Boulders

1½ ft. dia.	½ cartridge
2½ " "	¾ "
3 " "	1 "
4 " "	1½ "
5 " "	2 "

Larger sizes than listed require proportionately increased charges.

The extent to which the boulder is buried and the nature of the ground also influence the amount of explosive required.

A striking illustration of the action of a proper undermine blast. The rock is lifted a few feet and cracked, but is not thrown far. Look closely and you can see the cracks where they had begun to form at the instant the picture was made.

Kind and Grade of Explosive

Probably the most economical explosive for breaking rock in this way is 30% to 50% strength dynamite of either the nitroglycerin or ammonium nitrate class. On account of the better confinement secured in this method, stones can be broken more effectively and successfully with slower and less powerful explosives than by mudcapping. 20% to 40% strength dynamite often will prove satisfactory. Any standard strength of nitroglycerin, ammonium nitrate or gelatin dynamite will do the work.

To roll stones out without breaking them, the high percentage explosives can be used successfully, but they are not as well suited to the purpose as the slower ones, such as 20% ammonium nitrate dynamite. If you are buying explosives for breaking rocks, however, buy those best suited to the actual breaking, and do the rolling out of the stones with the same explosive.

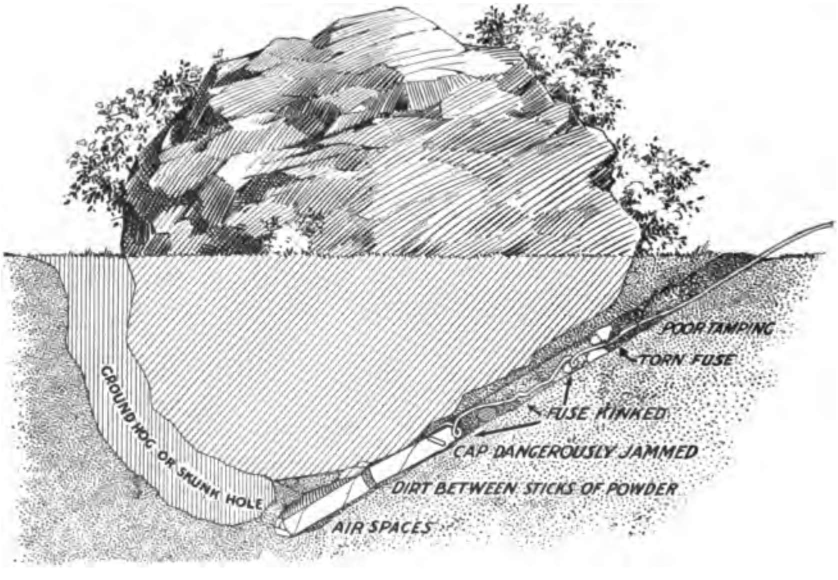
Tools

The tools needed in snakehole or undermine blasting of boulders are the testing rod or probe already mentioned, a shovel for handling dirt, a crowbar or dirt auger, a wood tamping rod 1¼ inches in diameter, and a cap crimper. Several other items in the tool list can be made use of to good advantage where there are many stones to undermine. One is a 3-inch fence post, to tamp the ground tight about the edges of the stone. Another is the scraper, for enlarging the bottom of an auger hole.

Cost and Time

Undermine or "snakehole" blasting is a slightly cheaper method than mudcapping when conditions are favorable. It is often found that the cost per cubic yard increases with stones smaller than one cubic yard, and is very much less with stones containing several cubic yards. Sandstone has cost ten to fifteen cents per cubic yard to break in this way, and the other kinds in proportion. This is one of the most serviceable and satisfactory methods of blasting boulders. The cost can be calculated by referring to table on page 21. Add labor cost to the total for explosives. Sandstone and other such easily broken material can be broken up cheaply, while marble and trap come higher. Although the cost of explosives is somewhat less than with the mudcap method, this is partly offset by the additional labor required in making the holes in the ground. Ordinarily a man can make a hole and place a charge under a stone in 15 to 20 minutes.

Combinations of snakeholing and mudcapping sometimes are effective with stones that lie on the surface of the ground or are imbedded only a little.



A combination of evils. Such loading could not result in breaking a boulder. Note the seven faults.

Suggestions

To make use of the advantages of such a combination an electric blasting machine to produce simultaneous exploding is necessary. It is not wise to attempt the combination of top and under shots when a stone is buried deeply. Better roll it out first.

Cautions

Two points of caution are desirable. Beware of misfires. See page 164. Remember that snakehole or undermine blasting may throw pieces of rock with considerable force and range, but the danger can be reduced to a minimum if proper precautions are taken to see that every person and animal is out of range of flying rock and fragments. It is not unusual in snakehole or undermine blasting to see pieces of stone thrown more than 100 yards.

Blockholing

This method of breaking rock with explosives consists in drilling a hole into the boulder, putting the explosive at the bottom, tamping tightly, and firing in the usual way. It is remarkable how small a charge of explosive will break a big boulder, even of the hardest and toughest kind, when placed in this way. One cartridge of explosive in a drill hole 18 or 20 inches deep in a rock will do more damage than several cartridges on the surface.

Description

The blockhole method of blasting is the best way of breaking large, tough boulders that are not too hard to drill and which do not break well from a surface blast.

Drilling and blasting in a similar way is nearly always the only practicable method of blasting ledge rock.

Character of Rock and Placing of Explosives

The nature of the rock has a good deal to do with the point at which it is best to place the explosive. Ordinarily it will be found that the charge should be located somewhere near the center of the boulder, though different kinds of rock require different depths of holes. A brittle rock which does not split well and a tough rock such as trap, must be drilled deep in order to break it right, while a shallow hole will give satisfactory results in a rock which is easy to split, or which crumbles apart like slate.

A rule that may be applied to all rock is that the deeper the drill-hole, down to ½ or 3/5 the way through the rock, the less explosive will be required, and the greater will be the execution of the blast. In boulders that are very hard, and so big that they require a large charge, it once in a while pays to drill a very small hole, and then spring this hole at the bottom by exploding at that point a small charge of explosive, using no tamping. Such a practice will be needed rarely in boulder blasting, though it is often useful in blasting out ledges.

Drilling Facts

Holes may be drilled by one man alone, or by two or more men. One-man drilling usually is the cheapest when holes are made by hand. The drilling can be done with ordinary hand hammer drills, with churn drills (finishing deep holes), or with machine drills.

Hammer Drills

A hand drill is just a straight piece of drill steel, which is medium hard and very tough, with one end shaped into a proper cutting bit. This bit is ⅓ to ½ or more wider than the shank of the drill, with the cutting edge somewhat rounded up to the corners and sharpened in the form of a "v," the angle of which should be long and thin or short and thick, according to the kind of rock to be drilled. In soft rock use a long thin cutting edge; in hard rock a short, thick edge.

You can buy drills of different lengths and diameters from mine supply houses or hardware dealers anywhere. Or you can buy the steel from hardware stores and make them. Drill steel comes in ⅝-inch, ⅞-inch and other diameters, in bars up to 20 feet long. If you plan to make your own drills, be sure to have on hand a good length of it, for even if you have only a dozen boulders to blast you will need several drills as they require sharpening frequently.

If one man is to do the drilling, the hand hammer should weigh 3 or 4 pounds; if two men, 8-pound sledges are about right. All hammers should, of course, be flat faced. The drill should be turned about ⅛ of a revolution at each stroke of the hammer so as to keep the hole round. The more regularly this is done the nearer true the holes will be and the faster the bit will cut. The holes can be started with a short drill—say 8 or 10 inches long—easier than with a long drill.

Size of Holes

The right diameter for a hole in a boulder usually will be about one inch. It is well to keep the hole as small as possible, for it takes a good deal longer to drill a big hole than a small one. For instance, it takes about four times as long to drill a 2-inch hole as one an inch in diameter. If the 1-inch hole will contain enough explosive it should be the size selected. But it must be remembered that as the hole goes down, the ears of the drill bit will wear off and the hole will grow smaller, so that in hard rock it is well to start a hole that is to go deeper than a foot or so, with a drill ¼ inch larger than is wanted at the bottom. In boulders containing more than 6 or 8 cubic yards of material it is best to drill inch or inch and a quarter holes.

The holes should be kept wet by pouring in water as the drill goes down. In this condition, the drill cuts much faster than in dry holes. It is necessary to keep the holes clean. The sludge, as the ground-up rock is called when mixed with water, can be taken out with a scraper which is shaped somewhat like a very small garden hoe, or with a spoon rod, which is a small wood rod with a disc of tin on each end. The discs should be of different sizes, and at

Pressing in the tamping after a charge of explosive has been seated in the bottom of a blockhole.

one point they should be cut to the center and one of the cut edges bent down, so that when the rod is revolved in the bottom of the hole the edge will scoop up some of the sludge.

Another good way of cleaning out holes is to use a spiral hook, or drag twist, like an old-fashioned rifle cleaner. Rags or hay can be used on this to wipe the hole. A hickory or willow stick with the end split into many small pieces, or broomed, is also a good thing for getting dirt out. When this is dipped in the sludge, the material sticks to it, and can be lifted out and knocked off against the outside of the stone.

A leather or rubber washer, or some old rags, should be fixed round the drill just above the level of the stone, to prevent the sludge and dust from flying up into the face of the driller. This is particularly necessary when churn drilling.

Churn Drills

A churn drill is a piece of drill steel from 5 to 6 feet long, often having bits at both ends. It is used without a hammer—a man raises and drops it into the hole. Holes cannot well be started with it. It will cut holes faster than a hammer drill under favorable conditions, but owing to the way it is worked its use should not be attempted in holes less than 6 or 8 inches deep. For deep holes and in soft rock it certainly should be considered. A good churn drill for 1-inch holes should weigh about 10 pounds.

Sharpening Drill Bits

Bits should be kept sharp, for dull drills do only a fraction of the work they should. To sharpen bits costs about five cents each. It may be done in a blacksmith shop or, in emergencies, with a file or on an emery-wheel or grindstone. They should be made as sharp and hard as they can be used in the rock to be drilled without either dulling too fast or chipping. The angle of bevel that is best generally will be about 90 degrees for hard rock and 45 to 60 degrees for soft rock. Your blacksmith will give you the proper kind of bevel if you give him the necessary information. Good drill steel is not tool steel.

Before attempting to sharpen a drill the shape of a new bit should be observed. Heat the drills to cherry red, and do not hold them long at that temperature. Work to get them hot without delay, then take them out of the fire promptly for dressing.

The bit should be hammered to shape on the anvil, with the shank of the drill held so that it has 1 foot rise to 2 feet of length. You likely can use a file to advantage to help shape the edge, while the steel is hot. When the bit is shaped, it is ready to be put back into the fire and reheated for tempering.

Tempering Drills

The tempering should be started when the steel is at a temperature of 430 degrees F. You can tell the temperature by the shade of the surface or color film that forms on the surface as the steel is being heated. When the bit has been heated slowly until the surface has nearly a cherry red shade, take it from the fire and hold it in the air till it gets a very pale yellow. Rub it on a stone to remove the scales so the color can be seen unmistakably. If it seems to take too long to reach this color in the air, plunge it into the water and out again at once to start the cooling. Then watch the colors by standing in a dark corner. They should advance parallel to the edge. If they don't, hold the hot corner or side in the water an instant to even up the entire bit. As soon as the very pale yellow color is noticed, stick the bit into cool water and leave it there, stirring it about till most of the heat has left the steel.

Temperatures of the steel that are indicated by the colors are as follows:

Very pale yellow	430	degrees F.
Straw color	470	" "
Brown	490	" "
Purple	530	" "
Full Blue	560	" "
Dark Blue	600	" "
Cherry Red	900	" "

How a proper blockhole blast will shatter a boulder into pieces of all sizes. Note how completely the stone is broken throughout its entire volume and not just at one side or corner.

Time for Drilling

The time in which two men with hand drills can make holes in rock can be told best by stating the number of minutes it takes per inch of hole in different kinds of rock. For beginners, when two men are drilling holes an inch in diameter in rock such as sandstone, about 2½ to 3 minutes per inch in depth is required; in limestone 3 to 3½ minutes; in granite 4 minutes; in mica schist 5 minutes; in marble and trap rock 6 to 8 minutes. Single hand drilling (one man) proceeds about two-thirds as fast, except that in soft rock the rate is upwards of three-fourths as fast and in very hard rock only half as fast. These figures change greatly according to the experience of the workers and the condition of the sandstone, limestone, granite, schist, marble or trap rock that is drilled.

Machine Drilling

Machine drilling is very much faster than hand drilling, and much cheaper where there is enough drilling to do to justify the purchase of an outfit. Since there are many owners of large acreage which requires clearing, also many contractors in stump and stone removing who will use this handbook, some of the data about machine drilling will be useful.

Speed

In clear rock, or rock not checked, machine drilling is 5 to 15 times as fast as hand drilling. In some sandstone it is possible to go down at the rate of a foot in 5 minutes (instead of an inch or two as in hand drilling); and in trap rock at the rate of a foot in 10 or 12 minutes. In limestone the rate is even faster than in some blue sandstone, there being records of instances where a foot has been drilled in 3 minutes. Hard granite and flinty rock often drills at the rate of a foot in about 7 minutes.

Cost

Blockhole blasting is more economical than undermining, the cost depending partly on how difficult the rock is to drill. Blockholing requires a smaller amount of explosive and larger amount of labor and time than mudcapping or "snakeholing."

The cost of machine drilling usually is much lower than of hand drilling—often it is about one-fourth or one-third, of course not including depreciation or interest on the cost of the outfit. This is much or little per foot of hole drilled, according to how steadily the outfit is used. It may amount to only a fraction of a cent, or it may run the total cost up higher than that of hand drilling.

How a boulder can be broken into pieces small enough to handle easily without shattering it into fragments, with proper charges of 20 per cent. ammonia explosive placed in a blockhole, or by 40 per cent. explosive used as a mudcap. This stone shows by its breaking how joint and bed lines run.

Machines

There are two types of machine drills operated by steam or compressed air—the small jack hammer type and the large tripod drill. The jack hammer drill is the best type of machine for use on boulders. Jack drills are portable and easily handled. Tripod drills are heavy.

Other Tools

The tools needed in blockhole blasting, aside from drills and hammers, are a pocket knife for cutting fuse or scraping wires, a cap crimper and a wood rod for tamping. Crowbars are often useful.

Kinds and Grades of Explosives

The kinds and grades of explosives that can be used for blockhole blasting are many. In fact, rock can be broken by this method with almost any blasting explosive. But certain facts should be understood by blasters. One is that the use of a high strength quick-acting explosive, such as 50% or 60% dynamite will shatter rock into small pieces, while the use of slower explosives such as 20% strength will crack and split it into larger pieces. Ammonium nitrate dynamites are considered somewhat superior to nitroglycerin explosives for this purpose. For the ordinary breaking of boulders into pieces small enough to handle easily, there is nothing better than 20% to 40% ammonium nitrate dynamite.

Amount of Explosive Required

In blasting in quarries, 5 tons of rock often are brought down per one pound of explosive. It is difficult to maintain this ratio in the field, unless it be with very large rocks, or ledges with an open or free face. Small boulders often require more explosives per cubic yard than large ones. The shape of the boulder is also an important point, so the following tables can only be considered as approximate.

Approximate Number of Pounds of Explosives Required to Break Boulders by the Blockhole Method, per Cubic Yard of Rock

Sandstone and other more easily broken rock	¼ lb.
Limestone and other medium rock	⅜ lb.
Marble, trap and similar hard, tough rock	½ lb.

Figuring on the basis of the diameter of the stones and the number of cartridges of explosives required, the tabulation is:

Approximate Number of Cartridges of Explosive Required to Break Boulders of Different Diameters

	Sandstone, Slate and similar easily broken rock	Limestone and other medium rock	Marble, Granite, Trap, and similar hard, tough rocks
1½ ft. dia.	¼ cartridge	¼–⅜ cartridge	½ cartridge
2 " "	⅜ "	½ "	¼ "
2½ " "	½ "	½ "	1 "
3 " "	½ "	¼ "	1 "
4 " "	1 "	1¼ "	2 "
5 " "	1½ "	2 "	3 "
7 " "	6 "	8 "	10 "

Often from experience, an observant man will learn just how much explosive is required to crack a stone and lay it apart without excessive throwing of pieces, danger and waste of explosives.

Loading Charges

All water should be wiped out of the holes. If the holes are smaller than the cartridges of explosive the paper wrapping of the sticks will have to be removed and the explosive pressed into the hole so that there are no air spaces. The cap should be placed in the charge near the top. Tamping of damp or wet clay or other earth should be placed solidly over the explosive to the mouth of the hole. Results of the blast with the smallest charges will be poor unless there is at least 6 or 7 inches over the powder.

An undermine blast that was too heavy was used here to break a very hard, tough boulder. As a consequence the rock is broken only into large pieces and these are thrown long distances. A better way would have been to have used a very heavy mudcap blast on top of the rock, or, still better, a proper blockhole blast.

Firing

The firing of blockhole charges may be done either with fuse and cap or by the electric method. If more than one charge is to be fired, the electric method will enable you to put them all off at once. Electric firing is of much advantage in blasting out ledges, and also in firing the very small charges sometimes used to break stone to certain dimensions.

Sometimes what may be called a "semi-mudcap" blast can be used in very hard stone, or in stones that are difficult to drill. Drill a hole into the stone for 3 to 8 inches, fill with explosive, let the rest of the charge of explosive pile up on top of the rock as you would a mudcap charge, in a low cone with steep edges. Cover this with 6 inches or more of wet clay.

Suggestions

Boulders that are buried may be thrown out of the ground before they are blockhole blasted. When the earth is supporting them on all sides they may not break quite as well. Digging round them or raising them off the ground with a jack or pry, and letting them rest on small stones placed under the ends or corners, helps to break them up better.

Breaking Ledges

Blasting in drilled holes is practically the only method that is effective in breaking up ledges of rock, either underground or above the surface. Drill a line of holes along back of the edge or face of the ledge above the surface. It is not necessary to dig or blast away the dirt from a ledge. The quantity of explosive required can be gauged by the table giving the amount to use per cubic yard of rock. Use half again as much explosive in a ledge blast as in a boulder. Measure the distance from the open side or face of the ledge back to the drill holes, and compute the number of cubic yards that should be broken off.

Ordinarily on farms or in roads it is desirable to break up ledges to a depth of about 2 feet below the surface. To do this the holes should be put down slightly more than 2 feet and should be located 2 or 3 feet back from the face of the ledge. To break ledges deeper, drill deeper holes farther back from the face and charge heavier. The deeper holes can also be farther apart. Two-foot holes usually can be 5 feet apart in soft, brittle shale and slate, 4 feet apart in limestone, and 3 feet apart in harder material. The spacing between the holes should be about the same as their distance back from the face. The details of charging holes, drilling, tamping, firing, etc., that have been given for boulder blasting apply equally to ledge blasting.

Blockhole blasting is perhaps the most efficient method of breaking rock that is known, and from it you can expect perfect results. If you use a proper charge of a quick explosive, the rock will be shattered into small pieces. If you use a slow explosive, the rock will be broken into larger pieces. In any case, the use of the charges recommended here will result in the satisfactory breaking up of any rocks you may have to deal with.

Results to Expect

How boulders are shattered into fine pieces by heavy mudcap charges of 60 per cent. nitroglycerin explosive. Note the amount of stone that is so small it will not need to be hauled away.

General Considerations

The information on boulder blasting, and particularly on the breaking of ledges of rock, applies to quarrying limestone or road material, gravel, etc. In quarrying, it is better to drill larger holes than one inch. Proper loading in inch and a half holes, drilled to depths of 6 or 8 feet, and 5 or 6 feet back from the edge of the quarry ledge will loosen large quantities of rock.

Quarrying

It does not pay to dig hard-set gravel or sand by hand, for in such material the holes are easy to drill, and comparatively small charges of explosive will loosen great quantities. For quarrying use 40% ammonium nitrate explosive unless the rock is wanted in large pieces, when 20% ammonium nitrate grades will be better. For the semi-rock, hard gravel, etc., use 20% explosive, the granular powder known on the market as R.R.P., or if the work is dry, black blasting powder.

Explosives as a Labor Substitute

Emphasis should be placed on the possibility of using explosives as a labor substitute. To illustrate, take the disposal of a 4-foot sandstone boulder. To drill this with an inch hole 32 inches deep would require about 1½ hours, or slightly less, for two men. But one man can smash the same boulder within 10 minutes by placing a proper mudcap blast. In the first case the breaking of the boulder is achieved with greatest economy in total outlay, but in the latter case it is broken by one man, and broken without interfering seriously with other work. On many farms there is so much to do and men are so scarce that to take the 1½ hours for the boulder's removal is out of the question, and the boulder remains in the field—unless it can be broken up with little labor and loss of time.

Disposal of Pieces

When a boulder that is nearly all buried is rolled out and blasted, there likely will be room in the hole for many of the large pieces, deep enough to put them all below the plow line, but it is not well to bury pieces larger than 6 inches in diameter, as the broken rock will be valuable for building purposes, for road making, lining ditches, etc., and should be kept in the stone pile until needed.

Hauling

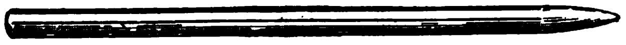
It costs about 35 cents a cubic yard to haul pieces of stone away, figuring on the average haul. Solid rock of average density weighs about 2 tons to the cubic yard and loose material as it falls weighs about 1⅓ tons to the cubic yard. It is better to put a stone rack on a wagon if a wagon is used. Such a rack can be made of 2 or 3 inch plank. To get heavy pieces of stone on the wagon, use planks to skid or roll them up. If the pieces are very heavy, use a "stoneboat" instead of a wagon. It is better for short hauls because it saves so much lifting. An average load of stone is about a ton and a half, and two men will handle this in about half an hour, including loading and unloading.

Filling Holes

The holes from which boulders have been taken should be filled level, to avoid a low place in which water will gather during wet weather. To fill the depressions, a horse drag scoop such as is used in excavating dirt is a useful thing. If this is not available, a good thing to use is an ordinary road drag, or a split log. By standing on the drag or log it can be made to gather a lot of ground, and the dumping can be done by taking off or shifting your weight.

Tools and Appliances

In addition to various tools described under the separate headings on methods, blasters of boulders will find a heavy crowbar and an iron wedge to be useful at times for prying apart pieces of rock. Some blasts will be found not quite heavy enough to throw the stones apart, though they will crack the rocks through and through. These stones can be reduced with a sledge, but a little prying will accomplish more than a whole lot of hard hammering. If the bar cannot be forced into the crack use the wedge and sledge it in. Be careful that the wedge does not strike solid rock at a bed or joint line running at right angles. The wedge should be a slim piece of tough steel, 6 inches long and an inch or two thick at the base.



Steel bar for making holes.

Soil auger—note long point.

Tamping

The best tamping material is damp clay. Tamp the hole full, while working in the tamping with the stick in one hand, hold the fuse or the electric wires out of the way with the other hand. It is easy to damage fuse and wires by breaking the insulation with a pebble, or with the edge of the tamping rod. It is also easy to pull the cap out of the primer charge unless the fuse or wires are held firmly against the rock. Many misfires are due to carelessness at this point.

In lighting a fuse, stick the flaring head of a burning match right against the powder in the end. See page 159. This will work in any wind. The fuse always gives a pronounced spit as soon as it is lighted. Do not leave before the sparks and smoke begin to spit out regularly.

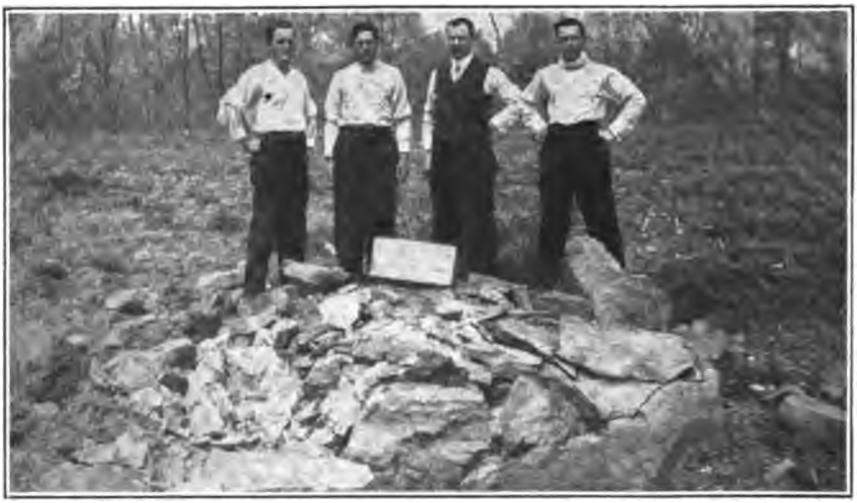
Flying Pieces

It may be safe to stand 100 to 150 yards away from a blast that is not overloaded, but this is a matter which each blaster will have to decide for himself. Much depends on the proportion of the charge to the boulder, its location, and whether the stone is solid. The right charge will not throw stone far, but a charge that is too heavy, or in the wrong place, will throw large pieces for long distances. In fact, this is one of the ways in which you can tell whether or not you are using too much explosive. In any case, to be safe, keep an eye on the blast and dodge any flying fragments coming your way.

Use every care to keep everybody beyond the range of danger. The man who fires the charge should keep his eyes open for stones coming down several seconds after the blast and at distances 100 yards or farther away.

Watch Misfires

They are dangerous. See page 164 for discussion of their cause and remedy.

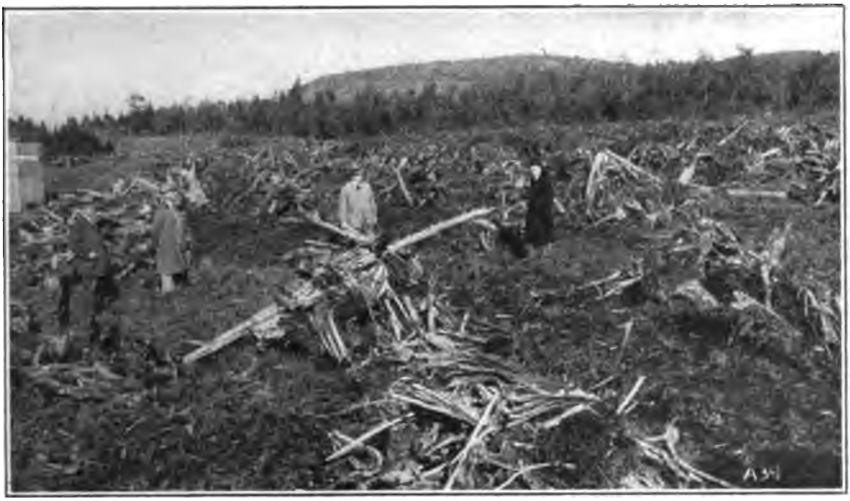


How a large granite sandstone or limestone boulder can be shattered with a mudcap blast. At the point next the explosive the stone is broken into small fragments, but at the other side it is left in large pieces, though it is well cracked in every direction.

CLEARING LAND OF STUMPS

To Clear or not to Clear

A "stump" may be defined as any kind of a growth that obstructs land, whether it is the butt of a cut tree, a tall snag, a living tree or a bunch of sprouts or brush. From the viewpoint of a farmer it is a stump if it obstructs the plowing and other tillage of the land.



The sort of wreckage practically perfect stump blasting should give. The pieces are shattered so they are easy to handle and so they burn well.

When Not to Clear

Before deciding to clear land, the owner should consider several features of the matter well. The reckless slaughtering of the timber has left in stumps many thousands of acres of land which is not fit for cultivation and that should go back into timber. Such land, of course, should not be cleared. On the other hand it is folly to permit brush land which has good soil to lie idle when a hundred years will not develop profitable timber on it.

Much land that is in woods now should be left so, for timber and for fuel. Every farm should have its timber tract, where the forest is conserved in a way to make it permanent. To cut young growth that will make good timber in a reasonable time is a mistake, no matter how good the soil is. Remember, too, the wind-break value of a piece of woods adjoining farm land, and consider the effect on land you now farm of taking away the protection afforded.

Do not clear land where the soil is too stony to be cultivated to advantage, or land that is exceptionally steep or incurably swampy. Do not clear when the profits would not justify the clearing. And do not clear when you can buy equally good improved land for less than the cost of clearing.

There is a certain sentimental satisfaction in clearing and cleaning up one's own place, connecting fields and improving it generally, even though such improving will not add greatly to the actual money income from the crops. This will have a bearing in some instances.

But hard-headed judgment should not be swayed too much by sentiment, for there are a good many thousands of acres that have been cleared and now are parts of farms, which it would be wise and profitable to plant to forest again. Lay out your clearing carefully. Include no corners, gullies or steep places you will afterwards neglect. And make sure your field is rightly placed in relation to the rest of the farm.

A fertile looking field which could not possibly pay a net profit of more than half what it should so long as the stumps remain as they are. Two or three years' gain in crops, or less, would pay for the blasting out of the stumps.

About new clearing there may be some question, but about taking out stumps in good cultivated land there can be none. There are stumps in fields and along fences, roads, hedges and on home grounds. There are pastures that are pastures and not wheat fields or orchards because cultivation among the stumps is too inconvenient. There are old fruit trees and old shade trees that are diseased and a menace. All these should come out, and the quicker they come out the better.

Worth little even as pasture land, never rising in value, but potentially worth $100 an acre as soon as it is cleared. This is the sort of valley floor that makes splendid fields of oats, corn, alfalfa and other hay.

The Profit and Loss Account of Stumps

The man who is taking up the farming of cut-over land knows that he cannot do much until the stumps are removed. But lest he be tempted to permit some of them to remain in the cultivated fields, as many men on older farms are doing, it is well to point out some of the losses which stumps cause and some of the gain which their removal brings.

Appearance

No farm is well ordered when its fields are foul, and no farmer commands the respect of his neighbors when stumps are crowding out his crops. The loss in self-respect probably is even more serious.

In farming stumpy fields a man does not have that sense of having done his best, which is half the battle for success.

Tool breakage is another source of loss caused by stumps. Plows and furrows are broken, mowing machines and binders are both broken and racked and in some cases the use of machinery is prevented. Heavy engine tools cannot be used at all where there are roots in the ground.

Greater speed and ease of cultivation is a prime reason for taking out stumps. The use of gang plows, wide harrows and other modern labor- and time-saving equipment and methods is practical and economical only on land that is clean, both above and below the surface. And such use is becoming of more and more importance, as farm wages go higher and labor becomes scarcer.

When the stumps are as thick as the hay piles or the shocks of wheat or oats or corn there is something the matter with the farm system. They are boarders who never pay any bills.

The injury to horses often is much greater from a money standpoint. Spavins and sprains result from jerks against roots. Mares are caused to slink foals, young horses are made balky. The danger of injury to men is by no means absent. The kick of plow handles rupture many men, and every year sees its quota of broken arms and legs among farmers who try to plow, cultivate or mow among stumps.

Weed spread is a thing that must be charged up to stumps. They grow about the stumps, mature seed and pollute the whole farm.

Increased Production

Just as the presence of stumps tends to lower the value of land and to keep it down, clearing off the stumps will raise it and keep it on the increase. Once start to clearing away the stumps on your place and the neighbors and people who pass on the roads will take it for granted that the place is a paying proposition, worth developing. If you want to sell it, there is no surer way of adding a few hundred or a few thousand dollars to the selling price. To hold stump land for increase in value is a mistake. *Clear it up and force the increase.*

The actual gain in crops to be secured by the removal of stumps can be measured by the proportion of the total ground that they occupy. For instance, in many cases a stump takes up a square rod of ground. In measuring the value of the removal of stumps, the gain in crops and in speed and ease of working the ground should be compared, not with the total value of the crop, but with the net profit before stumps are removed. Thus, if a 25-bushel crop of wheat costs 20 bushels to grow, the addition of 5 bushels to the yield will increase the net profit 100 per cent. Two dozen stumps to the acre may occupy such a large part of the acre that their removal will double the net profit.

This is the typical appearance of much land that is very fertile and which would pay handsomely if in alfalfa or fruit. (Near Linville Falls, N. C.)

The clearing up of land can be made to mean something more than the financial profit it brings, for when properly handled it well can be made one of the links that hold the boys to the farm. Once a boy has helped to develop a property in a way that he enjoys he will remember that place as home as long as he lives. And boys will be enthusiastic over the clearing operations, with the necessary planning for new fields, the blasting and stump pulling, and the burning afterwards, if the work is managed along some of the newer lines which take out the drudgery.

The Essentials of Good Stump Removing

Before settling on a plan for removing stumps, it is well to have clearly before you just what is required.

The stumps must come out entirely, or at least deep enough so that roots never will catch plows or other implements. Stumps with roots must be disposed of as profitably as possible, used if possible, or burned cheaply. They often can be sold or used at home for firewood of some kind, or sold for extract purposes. Failing this, they must be burned on the ground with as little damage to the soil as possible. In any case they must be broken into pieces small enough to handle by hand, unless derricks and power are to be used to handle them.

When all the trees of a wood-lot are cut down, the ground seldom is protected from animals and so treated as to grow a new piece of forest. But it should either be put in forest or cleaned up and farmed. The green stumps should be let stand a season, then should be blasted out with about four charges each. They are almost impossible to pull economically.

The total money expense of the clearing project must be within the capital available for the purpose, and the labor and time required must not exceed the supply. The condition in which the ground is left also is important. The holes should be shallow, and the less littering and tearing up of the surface there is, the better. The work usually should be finished in time for planting a crop in the spring, for the loss of a year's time costs money.

These are the things which should be included in the plans for clearing.

Nature of Stumps and Conditions Affecting Their Removal

There are about 500 different varieties of trees which make stumps in America, and it is not advisable to classify them all in this bulletin. What is of value is to review the nature of their roots.

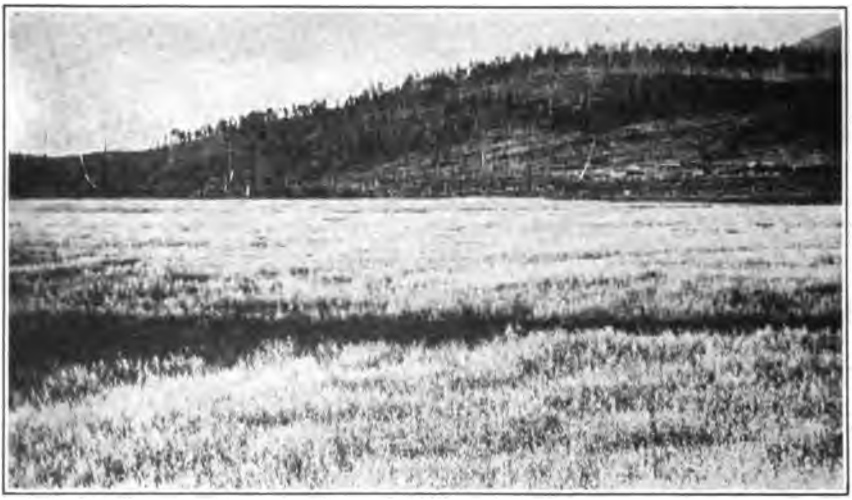
There are three general types of roots—lateral roots, semi-tap roots and tap roots. (See cuts, pages 53 to 55.) Some varieties of trees always grow in one way; other varieties grow in either of two ways, depending on soil conditions. The stumps of some trees rot fast, while others are very durable. Some roots die when the trees are cut; others throw up sprouts. The wood of some roots is tough and can be twisted a great deal without breaking; of other varieties it is brittle and will break off when bent or jerked.

Root Growth

Typical tap-root stumps are long-leaf southern pine, hickory and black gum. Some of these trees grow a root that is almost as big as the trunk, extending straight down into the ground. Others have slender roots. Sometimes these tap-roots send out lateral roots of some size, but in other cases the laterals are limited to hundreds of short, hair-like rootlets growing from the main tap-root. The tap-root itself sometimes splits at a point several feet underground into several smaller roots, all of them continuing to grow nearly straight down.

Typical lateral root stumps are elms, soft maples, locust, dogwood, elder, hemlock and some cypress. The roots of these trees grow in all directions from the trunk near the surface of the ground. Working the ground close about such stumps is next to impossible.

The largest class of stumps is the semi-tap-root class. Belonging to this class are white pine, poplar, chestnut, ash, walnut, red, black, pin and other oaks, persimmon and sassafras. Stumps of this class are harder to remove than either of the other two types, because the roots generally are big and strong and grow in all directions, some along the surface, others almost straight down and still others between.



Wonderfully productive meadows, for timothy, alfalfa or other grass, can be made by cleaning up and draining stump flats. This land was a tangle of old logs and stumps a few months before the picture was taken. (Michigan Land & Lumber Company.)

What may be classed as a fourth division is composed of the root clusters of sprouts and bushes of almost any sort of trees, whose growth has not yet taken the characteristic form. Brush of willow, elder, maple, chestnut, hickory, oak and witchhazel may be named. The roots are very firmly anchored in the ground for a distance of three or four feet in all directions.

The nature of the soil and the height of the water-table in it have much to do with determining the root growth. A hemlock tree, for instance, will send its roots down till they almost take on the nature of the semi-tap-root class in soil that is loose, free from stones and *dry*. The same tree would have few roots deeper in the ground than 6 inches where the soil is hard and the water-table near the surface. The root growth of other varieties of trees is affected by water and soil in the same way. A tree that grows on a steep hillside probably will have heavier roots on the sides than on the downhill and uphill grades.

A glimpse of primeval forest and of primeval stumps, the like of which few farmers meet in the eastern part of the country any more. Such land is expensive to clear but it is exceptionally fertile in most cases.

Rotting

Some stumps are durable and others will rot very fast. White pine, Norway pine, locust and cedar stumps will last fifty years without decaying enough to make much difference in the work of their removal. Chestnut, white oak and catalpa are nearly as durable. The other oaks, poplar, ash, hemlock, hickory and gum rot so fast that in a few years a team of horses can roll out stumps of considerable size.

It should be understood that during the first season, after any variety of tree is cut and the stump and roots die, the bark and soft outer layer of wood rots away, making the roots loose in their earth channels. It is the inner or mature wood which lasts.

Sprouting

Another characteristic of stumps which is of importance in clearing plans is their sprouting. None of the pine stumps will sprout when a tree is cut, but nearly all the hardwood stumps will do so. Chestnut is a great sprouter. A stump that does not sprout is not getting any worse as time passes, but one that does sprout is likely to be harder to take out each succeeding season.

Water

All kinds of stumps pull easier when the ground is wet than when dry. Explosives are more efficient in wet ground than in dry. Pulling machinery ordinarily is handicapped in very wet ground, because of the lack of firm footing.

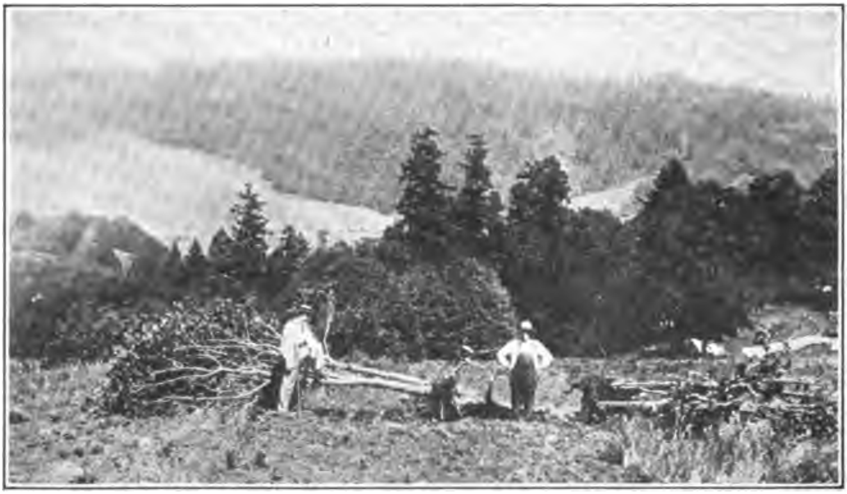
The nature of the soil, whether light or heavy, has a considerable effect on the way stumps come out of the ground. Naturally a loose, fluffy sand will hold the roots less than heavy clay. Pulling them out

This clump of trees was blasted out (not cut down). The stumps are torn out better than they might have been without the weight of the tops to pull them over.

of sand, therefore, is much easier than out of heavy soil. On the other hand, light soil will not confine the gases of explosives nearly as well as clay. In sand the greater ease of tearing the roots loose is more than offset by the lowered efficiency of the blast.

Kinds of Soil

The foregoing principles should be of more actual service to land clearers than a description of the conditions in different sections. If your stumps are Southern long-leaf pine, you know they will not sprout, and are of the tap-root class. If they are white pine of Michigan or Maine, you know they are of the semi-tap-root class, that they will not sprout and that they



This picture shows what they look like when down. The roots are torn out better than they would have been without the tops to pull them over. Note how easily they can be sawed or chopped.

When stumps are lifted by frost as much as some of these, they often can be pulled economically. They should be split up afterwards with light charges of explosive placed in auger holes or between roots, under a mudcap.

probably will outlast you if you do not move them. In case of a locust stump in Oklahoma, you know that you have a lateral root stump to deal with, that will sprout and that will last as long as the white pine. These illustrations serve to point out how every reader can classify his own stumps as to facts about them that are important from the clearing standpoint.

Methods of Clearing Land of Stumps

A half-dozen methods of removing stumps are more or less well developed throughout the country. Everyone who clears land, whether it is only the removal of stumps from cultivated fields or the clearing up of logged-off areas, should study the different systems in order to decide which of them is best under any particular conditions. No one method is best all the time, and in nearly every case a combination of various means will be found most effective.

Lists of Methods

Digging out the stumps by hand.

Pulling the stumps. The pulling may be done with horses or machines. The pull may be direct, or may be doubled or tripled in force by means of blocks and cable or rope. If with machines, it may be with a traction engine hauling direct, a donkey engine hauling by means of a drum and cable, a capstan puller run by horse power or man power, or a tripod puller which lifts the stumps straight up. (See pages 44 to 50.)

Burning the stumps. The old-fashioned practice was to start a fire alongside a stump and keep it going till the stump was consumed. Charpit burning consists of keeping an intensely hot but small fire about the base of a stump under a covering of earth. Another method is to bore auger holes through the stump or part way through, to form draft holes and flues. A favorite method in some sections is to burn out the roots with a gasoline torch to a depth below the plow line.

Finally, there is the use of explosives to blast out the stumps.

Combinations of methods very often are valuable, and are recommended at proper points.

Stump Disposal

The land clearer must remember the necessity of disposing of stumps after they are out of the ground. It is expensive and difficult to haul or burn whole stumps. Several hundreds of pounds of earth nearly always stick to the roots of big stumps taken out unbroken. For this reason wherever it is possible to do so the stumps should be broken into pieces small enough to be handled easily before the job is considered done. There is no comparing the cost of burning stumps, when they have to be piled by means of a derrick, with the cost when they can be handled by hand.

Choice of a Method

Whether to remove stumps when they are green or to let them decay a year or more is a problem to be decided by your plans and the uses to which you will put the land. Newly cut-over land is clean. It has few weeds and no sprouts. In one season it will not develop much of this growth, but in two or more seasons it will, and will be very much harder to clear than it would have been the first year.

Green vs. Old Stumps

The stumps are hard to take out while they are green. It costs much more to do the work then than a year or more later, after the bark and sap-wood has rotted from the roots.

But it costs money to miss crops, too, and if you are ready to put the ground to work at once, it is folly to wait for the stumps to rot. To wait from summer till the following spring is not a bad idea, for that loses little or no time, and starts the rotting process which makes removal easier and cheaper.

Speaking in general of pulling and blasting, pulling the stumps probably is better and cheaper when the stumps are very small, and blasting when they are large. Where a large number of big stumps are to be removed a combination of the two methods is advisable.

When stumps are small or numerous they can be pulled by a team of horses hitched direct, by a capstan puller, traction engine or donkey engine, with ease and speed. The pulled stumps can be handled by hand directly, and disposed of without trouble. The same is true to a lesser degree when larger stumps grow small and shallow roots, which require but little power to lift and move.

Pulling and Blasting

For stumps larger than 3 to 5 inches, explosives can be used alone effectively and economically, though there are important considerations which modify such a rule. One of them is that of soil. Explosives work more effectively in heavy, tight soil, such as moist clay, than in dry sand. Therefore, in dry, light soil it often is cheaper to pull all the stumps not too large to handle without breaking up, while in heavy soil it usually is cheaper to pull only very small stumps that will come out easily, and to use explosives, alone or in combination, for everything larger..

Old, well-decayed stumps too big to handle should be removed with explosives alone. Small green stumps may be blasted out clean, roots and all, but large green stumps nearly always require a combination of methods, as,

This picture shows how the roots of large green stumps can be broken up for handling by proper blasting of the stumps. There is little reason in clearing a piece of land twice of the same stumps—once to free them from their beds and again to dispose of them—by pulling—when the job can be completed with half the trouble and expense by blasting and hand piling.

for instance, blasting and team pulling, or pulling with a capstan puller. The cost of explosives often can be cut down by making use of such a combination of methods. A heavy team, or other means of pulling, will take out roots after the ground has been loosened with explosives.

Tap-root stumps larger than your arm should be blasted. Tap-root stumps cannot be pulled to advantage, though when very small they can be broken off by a side pull. Where land is swampy on the surface, and roots consequently lie shallow, a heavy team often can rip out stumps by direct pull, even up to fifteen inches in diameter.

Large stumps that are pulled may be broken up afterward with small charges of explosives placed in auger holes, but in general it may be stated that large stumps should be blasted first.

The folly of pulling out stumps that are big, and then spending as much money in getting rid of them as it costs to pull them, will be plain to any one. They can be disposed of at a fraction of the cost when they are well broken up.

Capstan Puller

A more detailed consideration of the pulling of stumps probably is desirable. Pullers are most successful in the loose jack pine land of the North and the similar pine land in the South, and in clearing hardwood cut-over land where nearly all the stumps are small. They are particularly serviceable where the stumps stand close together, measure 3 to 6 inches and have root systems which do not bring up much dirt. Under such conditions a stump puller is a good investment, especially where there is plenty of man and horse labor available at low cost.

But it does not pay to buy a machine for a small acreage of clearing. It pays only where a considerable quantity of clearing is to be done. In vicinities where the soil is light and there are many stumps on newly cut-over land, several farmers should co-operate in the purchase of a stump puller and should help one another to use it.

A stump puller works to least advantage under clay soil conditions. Another factor is the water in the ground. The ground must be fairly dry when the machine is used, even though the stumps require harder pulls then than when the ground is water-soaked. In mud, horses soon become mired deeply. Pulling of stumps must be done in the summer or fall. Of course, they cannot be pulled when the ground is frozen.

Two large hardwood trees which stood close together and were blasted out at one shot, without cutting down. About eight charges were used. The cavity in the ground is small and the soil is free from tight roots.

A capstan puller can be used on a moderately steep hill, though the cost of pulling the stumps from such ground will be greater than from level land. Whenever it is desired to use a stump puller, have explosive materials on hand to blow out or to split and loosen any stump larger than about 5 inches.

Donkey Engine

A donkey engine outfit especially designed for stump pulling can be used effectively and with success. It makes an expensive outfit, however, and unless there are several hundred acres of clearing to do, consideration of it may be dropped. In the case of very large acreage, it is the logical form of capstan puller to use.

Traction Engine

A traction engine, pulling stumps direct, is a very effective means of getting stumps out. In fact, when such an engine is available it is doubtful if the purchase of any other machine ought to be considered. Both traction and donkey engine pulling is subject to the same limitations as pulling by any other means, and should be confined to such work as they can do to advantage in comparison with explosives or other methods.

The detailed consideration of the blasting of stumps may be short and to the point. The use of explosives reduces the labor of land clearing greatly. One or two men with explosives can do the work of a large crew with pullers or fire.

When to Blast

The stumps can be blasted out clean. Thousands and thousands of acres of stump land are cleared completely every year with explosives alone. While the use of some means of pulling in connection with explosives undoubtedly cuts down the cost on a large tract of clearing, the added ease and speed of the work of explosives alone is considered by many people to offset this economy. For small tracts or a few stumps it is foolish to provide pulling facilities. Do the work with explosives.

The blasting splits the stumps into pieces easy to handle, and to sell or burn. When it is not desired to blast stumps out clean, the charges can be kept down and the stumps split and the dirt loosened and thrown away from the roots. The blasting does the work in a short time.

The investment of money is kept down when explosives alone are used. There is no machinery or equipment left on your hands after the clearing is done. Yet the best use of stump pullers and of explosives is mainly distinct and different, and they should be considered, not in competition, but in combination. A good team and a supply of explosive material is a winning combination nearly every time, and explosives are bound to play an important part in nearly every land-clearing operation.

Digging out stumps is practicable under certain exceptional circumstances. If you cannot get explosives and if you have men who are doing nothing, they may be put to digging out stumps; but if wages have to be paid, such clearing is bound to cost four or five times as much as when the work is done by better methods.

This pine stump is burning freely, and likely will be consumed if it receives some attention. The roots were bared of dirt and the stump was split by a light charge of explosive. When stumps can be left to dry for a couple of months after such splitting, they will burn very well, though pine stumps can be burned immediately afterward with a little coaxing.

Big stumps such as this can be blasted out electrically much easier and better than with charges fired with fuse.

Burning by charpitting is a practicable and cheap method of getting rid of soft wood stumps of large size and of stumps in heavy or clay soil when the weather is dry for two months or more at a time. It is not successful in lighter soils. It is costly when labor must be hired for the purpose, and wastes time. This method of removing stumps is chiefly valuable for settlers of logged-off or cut-over land who must fight their way through with little or no money.

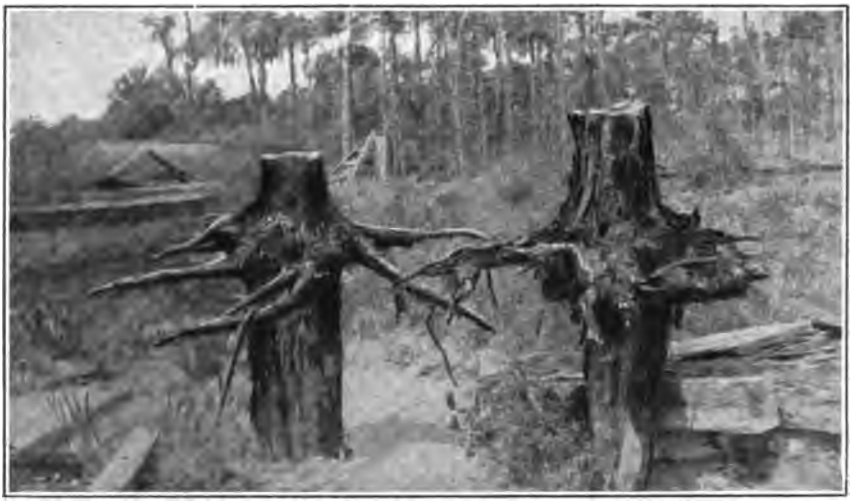
When to Burn

Burning by means of auger holes, and the use of oil, are freak methods not suitable for general use. They should not be attempted when the clearing operation is seriously intended to be economical. Burning with a torch of some kind is effective, but expensive.

Detailed Directions for Clearing Land of Stumps

Digging Out Stumps

If you dig right down after the roots, trenching to bare them, cutting them off with an axe first at the sides and then underneath, the stumps can be rolled out as though they were pulled. The cost is high.



Typical tap-root stumps, with the dirt washed away. To blast them out the charge must be located against the big root, four or five feet below the surface of the ground. Two charges to each root are better than one, though either loading will cut the root off successfully

Trench about Trees

If possible to know beforehand that you must dig stumps out, do it before the trees are cut. Dig a trench about them, taking away the support, and cut the lateral roots, and then let the wind and water finish the job. The water in the trench will soften the subsoil. The best time of year to do it is in the spring, when the wind is strong and the ground is loose.

Burning Out Stumps

Charpitting

Charpitting is perhaps the best method of burning stumps. The fire is kept burning at the base of the stump till it burns entirely through, and till the top is consumed as it settles down and the roots are eaten out to a proper depth below the surface of the ground. The fire is confined by a covering of earth.

Charpitting is effective only when heavy grounds can be secured to cover the fire. Sand, loam or other light soil cannot be used for the purpose successfully.

Conditions

The stumps should be reasonably dry, and the weather should be dry during the burning process, which takes two to six weeks. Light showers are not objectionable, but heavy, settled rains cause failure. Pine stumps burn best, because of the pitchy nature of the sap remaining. Any other soft wood can be burned this way. The successful burning out of hardwoods requires favorable conditions in all respects, and is rather doubtful in the hands of inexperienced operators.

The procedure is as follows: Remove the bark from the base at least. On some stumps it is necessary to dig away a little dirt. The fire should be started low enough so that it will burn in under the stump at the spaces between the roots.

Directions

Gather some fuel wood—any kind that will make good coals, though mixed oak and a little pine likely will be best. Cut this wood like stove wood—say about a foot long, and split fairly fine. Lay and stand the sticks round the stump till you have a layer at least 6 or 8 inches thick. You can pile wood and start the fire entirely round the stump, or only about a quarter of the way round as you prefer. Putting wood all round takes more wood and more time to prepare, but burns the stump out quicker and has more chance of success.

After the wood is in place it must be covered with a little straw, fern or other material of the kind, and then with a thin layer of dirt. The dirt layer should not be more than 3 or 4 inches thick. It must be of clay or very heavy soil. The dirt should be piled against the stump up to about 18 inches high, but no higher.

Start the fire at each quarter of the space round the stump. That is, if the wood runs only a quarter way round, start one fire; if all the way round, start 4 fires. Leave the holes where the fire is started open only for a little while, and then cover them up.

The fire must be kept covered all the time and never be allowed to burn into an open blaze. It is really smouldering and coaling of the wood. When the fire blazes much of the fuel supplied is burned up and the heat is lost instead of forced to eat its way into the stump. The object is to confine the heat. When this is properly done the fire becomes intensely hot round the stump.

As the stump burns through and the fire goes deeper, the dirt cover may break through. Such places must be covered with more dirt. If the fire burns higher up the stump than where the dirt is piled in the first place, put it out up there instead of trying to pile the dirt higher.

As soon as the stump is burned through, the top will settle down and continue to burn. Keep the fire covered over the ends of roots that burn off, so it will eat its way deep into the ground. If it breaks out to the air it will not burn far. While the stumps are burning they must be watched and visited several times a day.

The cost of charpitting in the manner described is high when the actual time of the operator must be accounted for at regular rates of wages.

Another good method of burning that really is charpitting of a modified form, is to saw the stumps off close to the ground, block up the top part, and to start a fire between the two sawed faces. The faces should be as close together as possible while allowing the fire to be started and to burn. Bank up the outside with dirt, as directed in preceding paragraphs, and keep the fire covered till the stump, roots and all, is consumed. Use stones to hold the two parts of the stump apart. It is best to do the sawing in the winter and raise the top part then, leaving it to dry out several months. The burning is done best in the summer.

Idaho Charpitting

Torch Burning

Burning with a torch is simply a matter of digging away the ground from the roots, and applying the intensely hot flame at a point below the plow line. Torch burning is expensive business when time and fuel costs are counted up. The best kind of a torch to use is one with a fan or bellows. The kind of fuel used by the torch is not important, except that some fuels burn better than others. Gasoline perhaps is best.

Plain Burning

A modification of charpitting sometimes is advisable in the case of pasturing the land for several years. The stumps are split and their roots uncovered with small charges of explosives. When they are thoroly dry, wood is piled between and over the split tops of the stumps and the whole thing is set on fire. With a little attention to keeping the burning ends of the roots covered with ashes and dirt toward the last, stumps may be consumed entirely by this method. It is not nearly so much trouble as charpitting, because the fire burns fiercely in the dry, shattered tops, and needs no attention other than the first piling of the fuel till it is time to look after the burning out of roots.

Pulling Out Stumps

Four forms of pulling are worth considering. These are by horses direct, with hand pullers and capstan pullers, and with donkey engines and traction engines.

Four Forms of Pulling

A good heavy team of steady horses will take out most of the stumps which should be pulled whole, and almost any roots left by proper use of explosives where blasting and pulling are used in combination. You will need a couple of good log chains and a regular outfit of singletrees and spreaders. To increase the strength of the direct pull, you can use a frame made of 6 by 6 pine pieces in the shape of the letter A. Make it 6 feet high. Attach a short piece of chain round the tip of the A, to run down to the roots over the top of the stump, or else run the main chain from the horses over the top of this frame before attaching to the stump. Such a haul will upset a stump much easier than a direct hitch.

If you have to pull without the frame, aim to pass the chain over the top of the stump and hitch to a root on the other side, the farther out the better. Another good hitch and haul is the twist. Hitch to a root and drive so that the chain tends to wrap round the stump.

When saplings are to be removed do not cut them first, but hitch the chain to them as far up as you can reach. While the team is hauling on them, a man should cut the roots on the opposite side with an axe.

A few days of stump pulling is enough at one time. Rest the horses and men at some other work. The clearing of land by this method is heavy and tiresome, and can easily become disheartening if kept up too long.

A capstan puller consists of a frame, a drum on bearings, a pole to hitch horses to, and a wire cable fastened to the drum. Some of them have gearing which reduces the speed of the drum and increases its pulling power. These work very slowly.

Capstan Pullers

The pullers have to be anchored to solid stumps near the place where they are set up. The limiting factor in the use of pullers is this anchor or anchors. When you pull, you do not always know whether the stump out at the end of the cable or the one behind the machine will come. To set the machine takes time, and you should be careful to make the anchorage as secure as possible.

If your puller comes without a pole, you can get one in the woods near home. Cut a 6-inch tree—ash, white oak, hickory or the like—and use a 20-foot length. Better attach an old wagon tongue to this where the horses are to be hitched, to keep the pole from hitting the horses when stumps give way suddenly. Some operators also attach a second pole in front of the horses, to lead them in the circle, saving continued driving.

It is better to wind up the cable on an empty drum; the cable wears much less in this way. For that reason use only enough cable to cover the drum—not two layers on it. The length of the cable will govern the area you can clear with one set of the machines. This usually will be about an acre.

Three men can clear an average acre of cut-over land of small stumps in one day. Three men will handle a small outfit. Handling the cable is heavy work, and you want no boys on the job. The hooks for catching the roots that come with the machines usually are poorly designed. You can have a better one made by welding together two old steel plowshares in a manner that your blacksmith will understand if you show him the original hook. For best results a hook should weigh about 50 pounds, though to be so light it must contain only good steel.

Time to Pull

Pullers are not suited for taking out occasional stumps in cultivated fields, but only to clearing cut-over land where stumps stand close together. The machine should be brought on the job only after the necessary blasting has been done. Then the small stumps and whatever roots are left by the blasting can be taken out at the same time. A supply of explosives should be kept on hand for blasting out the anchor stumps after the machine has done all the work it can.

A tripod puller is effective, but cumbersome to handle and expensive to operate. It is not recommended.

A donkey engine for stump pulling should have about the same power as for logging operations, and should be constructed about the same. There should be two drums, one for the pulling cable and the other for the return line, the return drum geared faster than on a logging donkey.

Donkey Engine Outfit

About 350 feet of pulling cable can be used. Inch or inch and a quarter cable usually will be best. The return line would be half or five-eighths inch. With 350 feet of main cable, 10 acres can be cleared at one setting. It speeds up operations to use a cluster cable with three or four books. Several small stumps can be pulled at once with this.

A donkey engine outfit requires five or six men to operate it. With it stumps of any size can be pulled. When they are too big to handle directly it is best to break them up with explosives before attempting to burn or otherwise dispose of them. Very large stumps should be loosened and split before they are pulled.

Traction Engine Pulling

Little needs to be said about using a traction engine. You will need heavy chains and heavy hooks. The chain should be nothing less than five-eighths inch. A short piece of inch or larger wire cable is better. Fifty feet or so is enough. The hook should be of steel, with one point, and should weigh 50 to 100 pounds. The entire hitching apparatus should be strong enough to stand jerking on with the weight and power of the engine.

Cost

The cost of operating pulling machines and of clearing land with them varies so much that no figures are safe to depend on. It depends on the kind of soil, the kind of stumps and especially on the skill with which the machines are operated. When everything is at the very best, land can be cleared economically with donkey engines and traction engines in combination with explosives. When conditions are not favorable the cost of these methods is very high.

Tools

For any kind of stump pulling you will need shovels, hoes, axes and bars. The probing rod also is useful for locating roots.

Blasting Out Stumps

The directions for removing stumps with explosives are given in full detail, and in order to do the matter justice they are placed in a separate chapter.

Blasting Out Stumps

A proper charge of explosives placed under a stump will tear the roots loose, lift the whole stump out, and break it into pieces. The whole operation is simple, safe, short and easy. Any sort of stump, of any size, in any soil, any weather, can be blasted out successfully, and the blasting is a practical and efficient method whether there is one stump to be removed from the middle of a cultivated field or a lawn, or thousands of acres of the heaviest logged-off land clearing to be done.

It is folly to attempt to blast out many big stumps, such as this one, without an electric blasting machine. Such a stump should have six to eight charges properly located about it. These numerous charges will contain less total explosive than one charge large enough to remove the stump. The hole they make is much smaller.

The best time of the year to blast out stumps is a matter of compromise between conflicting requirements. On the one hand explosives work most effectively in moist clay and wet sand soils. On the other hand, it is bad from a tillage standpoint to blast heavy ground when wet. (See page 67 for further discussion.)

With all the facts before you, the selection of time is a matter for your own judgment. If cost did not need to be considered, summer or fall would

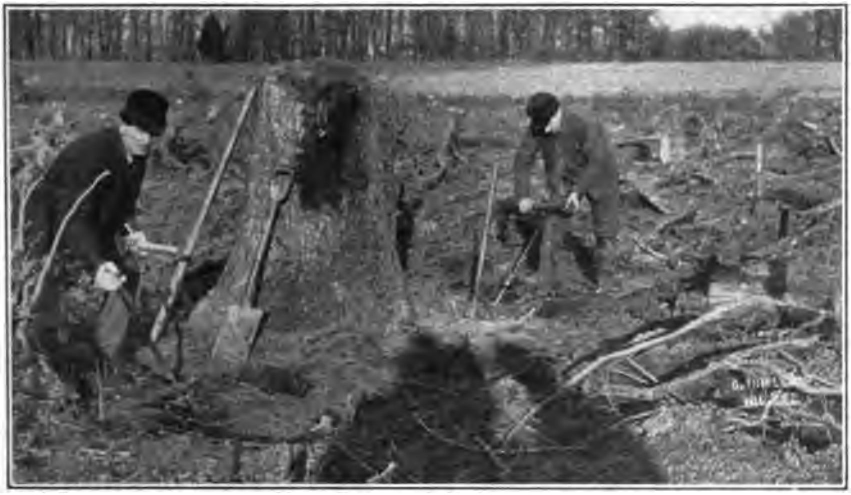
Time of Year

be ideal. Blasting out stumps from frozen ground can be done with satisfaction. In fact, the stumps are broken up better then than at any other time, though the work is harder on account of the difficulty of making holes.

Success, and especially economy, in stump blasting, is a matter of common sense and judgment plus some knowledge of the stumps and of explosives. Close attention to apparently small matters insures good work. The things that the blaster must consider are the location for the charges, the proper size of holes, the amount of explosives required, the length of fuse, depth of hole, tamping and the like.

Loading Charges of Explosive

To blast out a stump the explosives must be placed in a hole underneath it. Make the hole first. Then prepare the charge of explosives as directed on pages 142 to 150. Pack the explosives in the hole, tamp and fire.



In blasting out big green stumps, the holes for the three to eight charges should be made as nearly as possible under the main anchor roots. The man on the right is smoothing out a hole, getting it ready for the charge; the one on the left is shoving a cartridge home with the tamping rod.

Depth for Charges

Load stumps by no rule, but with regard to their root systems and to the nature of the soil. The aim is to tear the roots out of their anchorage in the ground, or to break them off below tillage depth. To do this you must place the charge or charges of explosives as close to their burden as possible—hitch them as short as possible to the load. The load or burden is not the weight of the stump so much as its grip on the ground. You must get good confinement of the gases. If there is a weak wall on one side of an explosion and a fairly solid or firm wall on the other, the weak wall will give way, and very little breakage or movement will be made in the other.

The charge of explosives should be located just deep enough to secure this confinement and to be under the load to be lifted, but not any deeper. If charges are too deep there is great waste of energy in uselessly lifting earth. This is costly. Charges that are placed too shallow will blow off the tops of stumps or split them, leaving roots tight in the ground.

The charges are placed and the wires connected, the stock has been chased away and the helpers warned back—now the blaster is ready to shove the handle of his machine down and to fire the explosive.

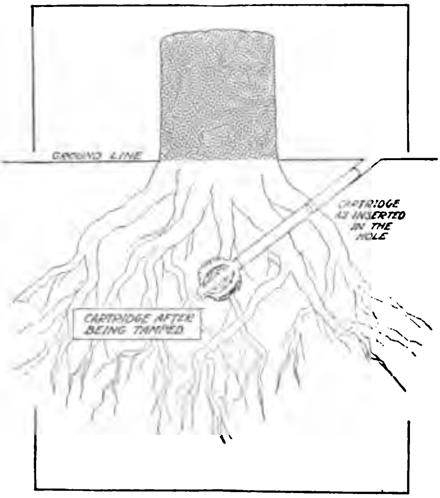
Since clay and other heavy soils hold the gases much better than sand, and wet ground holds them better than dry ground, a much thicker covering of dry sand is required over a charge to confine the gases properly than of wet clay. Charges, therefore, must be placed deeper in sand. Usually the charges should be placed right next to the wood of the roots in clay soil, and in sand with 6 to 30 inches of ground between the charge and the roots (tap roots excepted—see next page). Large stumps, and old stumps, require shallower placing of charges in proportion to diameter than small stumps and green stumps. Long-rooted stumps require deeper placing than short-rooted ones.

With the foregoing points in mind, it will be seen that the charges should be placed directly under that part of the stump that will give the greatest resistance. This may be the center, but it is by no means always so. If the stumps have grown on a hillside, the roots may be heavier cut sideways than uphill or downhill. Very often a tree on the level has heavier roots on one side than on the other. Usually it is of advantage to blast a big stump with more than one charge, placing one charge under each of the large roots and one under the center of the stump. A charge under a root should be at a point where the weight of the stump will be balanced by the pull of the ground at the other end. This point usually will be a foot or two out from the edge of the body of the stump.

In the foregoing suggestions, no mention has been made of the three main types of root growth—tap-root, semi-tap root and lateral root; but with the principles of blasting in mind, it is easy to see that a properly placed charge under a lateral root stump will be very shallow. If such a stump is to be taken out with several charges instead of only one, all but one of the charges will have to be located well out from the stumps proper, under main roots.

Semi-tap root stumps require deeper placing of charges than lateral root stumps. When such stumps are taken out with more than one charge, the points for the explosive are closer in, under the main roots where they dip a couple of feet below the surface.

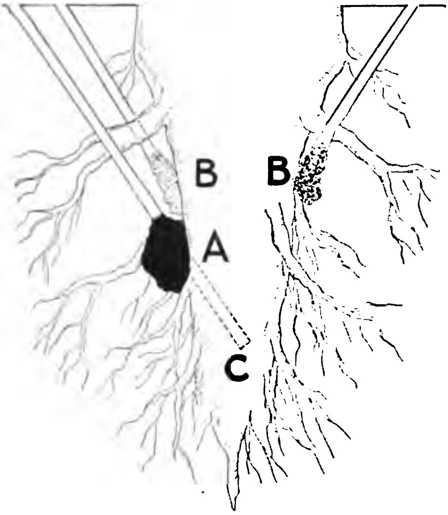
The underground nature of each stump should be determined before placing charge or even making holes. You can do this partly by observing the roots that rise above the surface, but mostly by probing down among the roots with the quarter-inch steel needle known as a probing rod. Every blaster should have one of these rods and should make use of it at each stump.


GROUND LINE
CARTRIDGE AS INSERTED IN THE HOLE
CARTRIDGE AFTER BEING TAMPED

How cartridges of dynamite swell and fill the hole when they are split and pressed with tamping stick.

There are two ways of blasting out true tap-root stumps. One is to bore a hole in the wood of the tap-root itself, and the other is to place the charges right alongside the root and against it, as mudcap charges are placed in stone blasting. In placing the charge in the wood, make a hole in the ground down to a point a couple of feet below the surface of the ground. Then bore a hole in the wood with a wood auger. This hole should go two-thirds or three-fourths of the way through the root. Fill the hole in the wood with explosives, fire, and the resulting blast will cut off the root.

In placing the charge of explosives against the wood, get it at least 4 feet deep. If you can command an electric blasting machine for firing, divide the charge in two and place the two parts on opposite sides. These charges may be placed only 3½ feet deep, though you should not hesitate to place the charges at a greater depth when blasting large tap-root stumps, particularly if the ground is of a light nature.

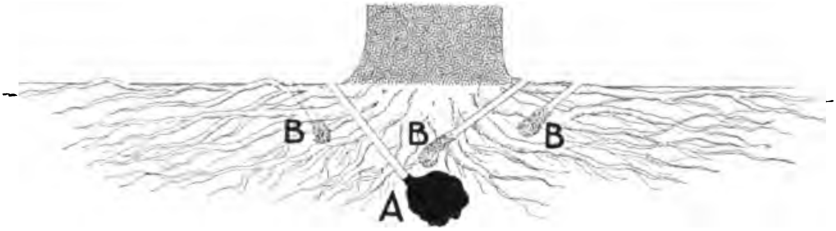


How to place charges for blasting out tap-rooted stump. Three methods are shown. "A" shows how to do it with one charge, using cap and fuse and not boring into the wood. "B" shows how to place two charges when electric blasting machine is available. "C" shows by dotted lines position of auger hole in wood where one charge could be placed to cut off the root and throw out the stump. Any one of the three methods will do the work.

In all sorts of stump blasting the holes for the charges can be dug with narrow-bladed shovels, spades or crowbars, or bored with dirt augers. (See page 61.) In stony land augers cannot be used, or can be used only for parts of the holes. All things considered, it is hard to beat the bar and sledge combination for making holes for charges of no more than two or three sticks, or for starting holes for larger charges.

Making Holes

The bored hole is better than the dug one because it can be tamped tighter. After much dirt once is taken out, it will not be tamped back in again as solid as it was before. Holes for inch-and-a-quarter cartridges of explosives should be made with inch-and-a-half augers or bars. In blasting exceptionally large stumps, use 2-inch or 3-inch augers. The holes usually can be started between roots and in depressions, but do not sacrifice good placing of charges for ease in making holes.

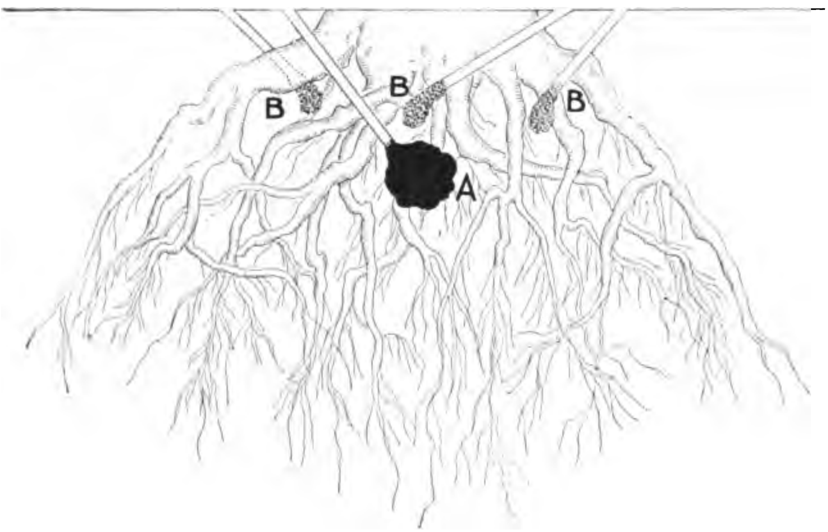


How to place charges under lateral rooted stump. "A" shows how to place charge when the cap and fuse are used and one charge is relied upon to remove the stump. "B" shows how to place three small charges under main roots when stump is to be removed with several charges fired by electric blasting machine. Use either method "A" or "B"—never both.

In water-saturated ground of a heavy nature, in case you have difficulty in getting the charge properly centered or placed (when no electric blasting machine is available for firing), you can make use of what is known as propagated detonation. Divide the big charge into several small ones in different holes bored from two, three or four sides of the stump, but all ending close together down under at the right point. If these charges are tamped solid and they are not more than a foot apart they all will explode at once when one of them is fired with a cap and fuse in the usual way.

In making holes for blasting out tap-root stumps, start the bar or auger straight down along the root from the surface. When you have reached the required depth, wriggle the bar sideways to make the hole wide at the bottom.

Wherever the number of stumps runs into many thousands, it will pay to get a machine to bore the holes. Such a machine will bore all the holes needed

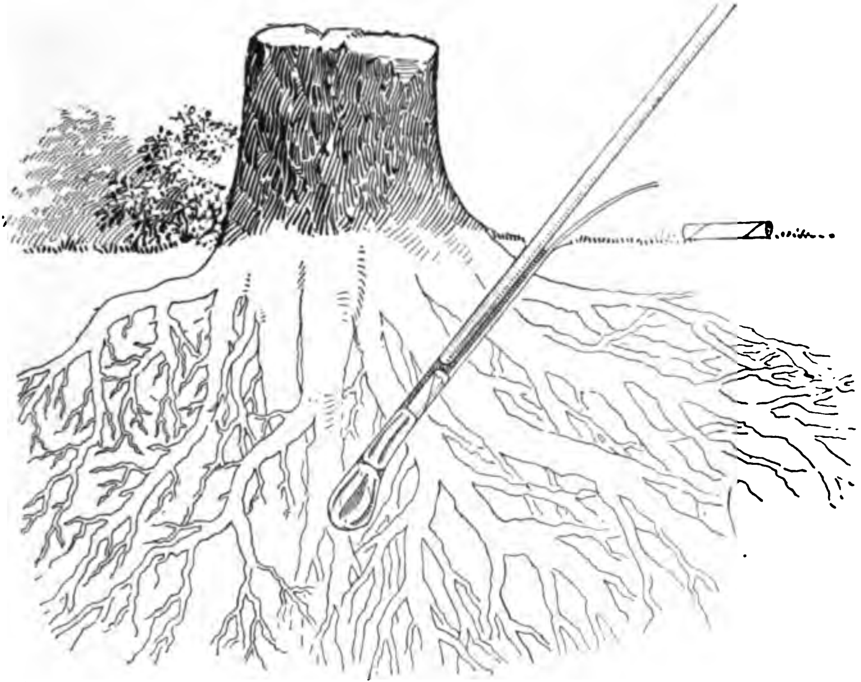


How to place the charges under semi-tap-rooted stumps. "A" shows proper position where one charge and cap and fuse are used. "B" shows proper positions of several small charges when electric blasting machine is used. Use either one or the other method illustrated—never both.

under the stumps at the rate of 500 or 600 a day, and at very much lower cost than the same work can be done for by hand. The machine bores almost as fast in wood as in earth, and is particularly serviceable when roots have to be penetrated in order to get the charges to the right spots.

Power Boring

Machines can be bought complete in small sizes suited to land-clearing purposes, or can be bought in parts and assembled on home-made frames. Electric machines are most convenient. Steam and compressed air machines are next best. Flexible shaft machines and direct-geared machines are least satisfactory. The flexible shafts break. The steam outfits freeze up and are troubled with burst pipes. All the outfits except steam ones can be run by gasoline engines.



To show cartridges of explosives expanded, as permitted by splitting of cartridge wrappings, in big hole.

An electric boring outfit consists of a small gasoline engine—say about 5 horse power—on a wagon belted or geared to a 3 kilowatt dynamo, and that equipped with two drill heads and 200 feet of electric cable. A supply of 1½-inch augers completes the outfit. Such an outfit costs about $500. You can use any gas engine. The dynamo will cost somewhat less than $250, and the drills about $80 each.

It takes five men to run this outfit—two men on each drill and one man to drive and to handle the cables. This man should lift the cables carefully over stumps and prevent them from kinking and getting caught. The steam and compressed air and the direct drive machines will not be described, because improvements continually are coming out. Watch the farm papers for advertisements, or write to any maker of explosives for names of manufacturers of these machines, if you are interested in them.

Study the methods of handling explosives as outlined on pages 144 to 150 and 167 to 170, to which every reader is referred at this point, before trying to load charges. A few special hints will be given here.

Slit Cartridge Wrappings

Charges of explosives usually should be as near as may be in a round bulk—not strung out for 2 or 3 feet in a long hole. To get them so the hole must be enlarged at the bottom by scraping or springing. Slit the paper wrappings of the cartridges and press the cartridges in the hole with the tamping stick till they swell to fit the hole tight and shorten to 2 to 4 inches in length. (See pages 53 to 55.) But do not do this if the hole is very wet.

When you have many stumps to blast out, it often is a good practice to make holes in the forenoon and then to load and shoot after dinner. Load and fire all the holes you have prepared when you go to the field, after which you can proceed to make more holes. *Always fire the charges soon after they are loaded.* To do this prevents missing charges, and avoids chance explosions due to meddling, and the like. If the holes are wet, firing immediately is required to avoid weakening of the explosive by water.

If you prepare your charges in the field, you can cut a supply of pieces of fuse before you go out. Make the pieces of varying lengths and crimp caps on them to prevent the powder shaking out of the ends. Take the roll along with you to provide for holes requiring longer fuse. Don't attempt to use pieces of fuse less than 15 inches long. They are dangerous.

Use plenty of earth when tamping the holes, and tamp well. See that the ground is packed solid, not only where you made the hole, but all around the stump. Often there are holes dug by skunks, groundhogs, gophers, squirrels, rats or mice under stumps. Keep the charge of explosives away from these cavities—better fill them up.

Some such appearance is necessary in stump blasting, but the less of it there is the better. The ideal blast is just strong enough, and is so located, that it rolls the roots free of their beds and splits them apart, but does not throw them an unnecessary foot. Loud reports and much dirt high in the air show careless loading and useless expense.

In lighting many fuses a gasoline or oil torch is useful. But there isn't anything much better than to stick the burning end of a freshly scratched match right against the powder in the end of the fuse. (See page 159.) Remember that the outside cover of the fuse does not burn, but the spark runs down the center as a drop of water might run down a tube. Do not leave the fuse till it spits sparks regularly.

None of your charges are likely to misfire if you load carefully, and if you have taken proper care of your explosive materials before loading. But if misfires do occur with fuse, do not investigate them for several hours, at least. (See page 164 for discussion of misfires.)

Misfires

Of course, in electric firing you can

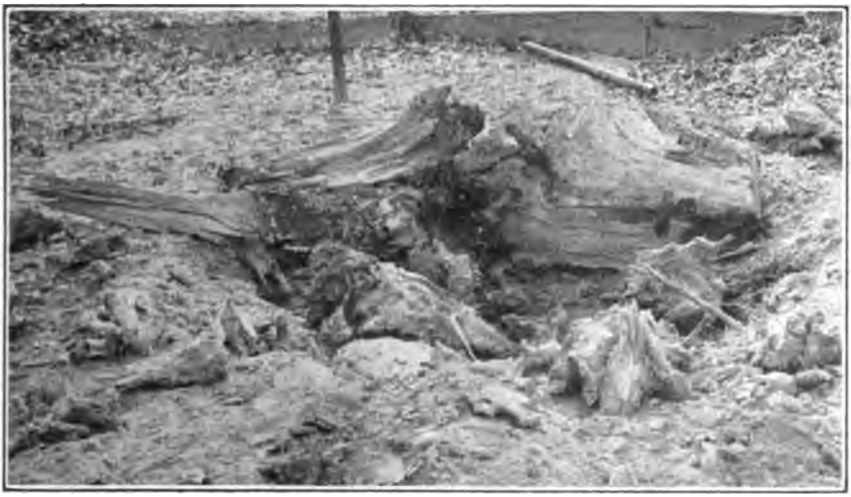
investigate a misfire immediately after the wires have been disconnected at the blasting machine.

Amount of Explosives Required to Blast Out Stumps

A proper charge of explosives for a stump blast has a dead, muffled report. It lifts out and splits the stump. Loud report and the throwing of the pieces far shows that too much explosives has been used. When stumps merely are split and tight roots are left, not enough explosives has been used (or it may be placed too shallow). If the explosion is muffled and does not throw pieces far, but digs too big a hole, the charge is too heavy and too deeply placed.

It is impossible to lay down exact rules for the amounts of explosives to use. This bulletin will include figures of amounts that have been used to blast out some stumps, but these figures must be regarded as correct only under identical conditions of soil, kind and age and size of stump, amount of water in soil, kind and grade of explosives, and amount of confinement in the hole. Experience must be the teacher in this matter.

A green stump requires a great deal more explosive than one that has stood a few years. More explosives are required in stony land than in smooth land to blast out stumps. The harder and heavier the soil is, the less explosives are required, and the looser and lighter it is the more explosives are required. Dry soil requires more explosives than moist soil.



As these roots lie, they show the result of an almost ideal blast. There is little hole in the ground; the stump is well broken up; the roots are cleaned of dirt; and no roots have been thrown very far.

When you want to blast a stump entirely out, it is better to load too heavily than too lightly, for roots left tight in the ground after the top of a stump is blasted off are hard to get out. If you are not familiar with stump blasting, start with the small stumps and load them as you think they should be after considering the various points explained in foregoing pages, and in view of the following figures.

Ordinarily it takes one pound of explosives for each foot in diameter of stump, when the stump is such as a white pine in clay soil cut 10 years or longer. Green stumps of any kind require more than this—usually about half again as much; sometimes twice as much. A rule for the enormous stumps of the Pacific Coast is to square the diameter of the stump, measured in feet, and use this figure as the number of 1¼ by 8 inch cartridges of explosives required. This rule usually over-estimates the amount required for stumps larger than 3 feet in diameter.

Examples of the incomplete job resulting from trying to blast out very big stumps having wide-spreading roots, with one charge to each one. Unless the charge is excessively heavy, which means that it is expensive in explosives and in loading, it can not be placed deep enough to remove the whole stump. Even if it is deep enough and heavy enough to be successful it is objectionable on account of the big crater made. Each big stump should have several charges.

Amount of Explosives Used to Blast Stumps

The following table is taken from records of blasting in Minnesota, Pennsylvania, Oregon, Kentucky, Michigan and Florida. The stumps were blown out effectively and successfully, and the figures should serve as a reliable guide.

Diameter Stump Inches	Kind Stump	Kind Soil	Cartridges 1¼ inch Dynamite
10	Pine, dead	Clay	1
12	Pine, dead	Sand	1½
12	Pine, dead	Loam	1
12	Pine, dead	Clay	1
14	Pine, dead	Clay	2
15	Pine, green	Loam	4
16	Pine, dead	Clay	1½
18	Pine, dead	Sand	3
18	Pine, dead	Loam	2
18	Pine, dead	Clay	1½
20	Pine, dead	Sand	7
20	Pine, dead	Clay	4
24	Pine, dead	Loam	5
24	Pine, green	Sand	10
24	Pine, dead	Sand	5½
24	Pine, dead	Loam	4½
24	Pine, dead	Clay	4
36	Pine, dead	Sand	10
36	Pine, dead	Loam	8½
36	Pine, dead	Clay	7½
40	Pine, dead	Clay	7
48	Pine, dead	Sand	13
48	Pine, dead	Loam	10

Diameter Stump Inches	Kind Stump	Kind Soil	Cartridges 1¼ inch Dynamite	
48	Pine, dead	Clay	9	
60	Pine, dead	Clay	15	
8	Oak, dead	Sand	1½	
12	Oak, dead	Sand	2	
12	Oak, dead	Loam	1½	
15	Oak, dead	Loam	1½	
16	Oak, dead	Clay	1½	
16	Oak, green	Clay	3	
18	Oak, dead	Loam	3	
20	Oak, dead	Loam	3½	
24	Oak, dead	Clay	3	
26	Oak, dead	Clay	2	
27	Oak, dead	Sand	5	
27	Oak, dead	Loam	4½	
30	Oak, dead	Clay	4½	
30	Oak, dead	Sand	6	
34	Oak, dead	Clay	4½	
38	Oak, dead	Clay	5½	
30	Fir, dead	Loam	10	
36	Fir, dead	Clay	12	
40	Fir, green	Loam	20	
48	Fir, dead	Loam	26	
72	Fir, dead	Clay	36	
60	Spruce, green	Sand	32	
15	Hemlock, dead	Sand	2	
10	Walnut, dead	Loam	1	
15	Gum, green	Clay	3½	
24	Gum, dead	Sand	4	
16	Black gum, green	Sand	5½	
16	Sugar maple, green	Sand	5½	
20	Snag, dead	Sand	4½	
6	Tap-root pine	Sand	½	Charge in wood
8	Tap-root pine	Sand	¾	
10	Tap-root pine	Sand	1	
12	Tap-root pine	Sand	1½	
15	Tap-root pine	Sand	2	
18	Tap-root pine	Sand	2½	
6	Tap-root pine	Sand	1	Charge against wood
8	Tap-root pine	Sand	1½	
12	Tap-root pine	Sand	3	
15	Tap-root pine	Sand	4	
18	Tap-root pine	Sand	5	

Proper blasts throw out little dirt. They pull the roots out of the ground, and permit most of what little dirt they do lift to fall back in the hole. In consequence good blasting leaves small holes.

An excellent plan for any blaster is to carry a notebook and a yardstick and keep track of the blasts he makes. Make note of the size, kind, age of stump, kind of soil, amount of water, kind and amount of explosives used, and the result of the blast, in each case.

The figures here given will serve as a guide for the first shots. As the work proceeds, base your loading on your own experience.

Here two charges, fired together electrically, were correctly proportioned and placed except that one was located too shallow and too far in toward the center. It should have been out under this remaining root, shown in the picture, which then would not have required pulling with horses or another blast.

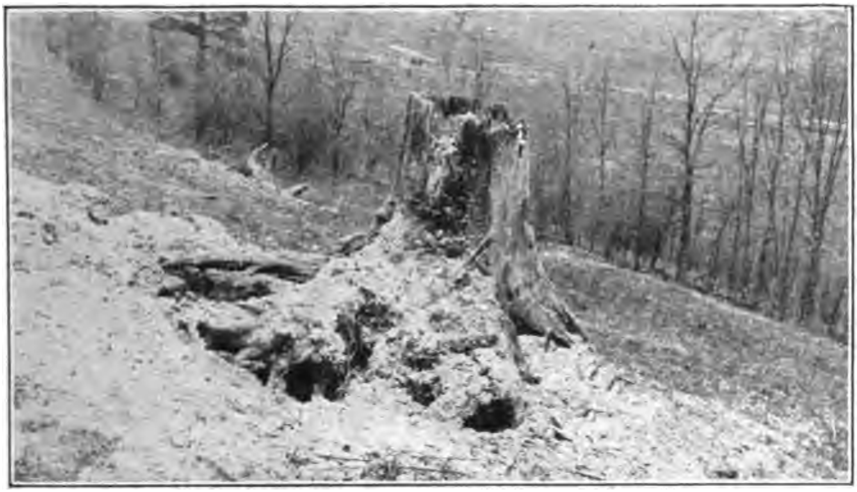
Kind of Explosives to Use

The kinds and grades of explosives best to use for blasting out stumps are few, and vary with the nature of the soil. In a heavy soil an explosive which cracks, lifts and heaves is more desirable than one which shatters. In other words, a slow-acting explosive such as 20% ammonia dynamite is the best to use. If the charges must be exposed for some time to water, nitroglycerin dynamite had better be used.

The single charge under this stump was placed too deep and too much to one side. It exhausted most of its energy in the ground far below the roots, and then what was left escaped between the roots, blowing the dirt away but not having enough power to carry the roots with it.

In dry, light soils, such as dry sand, it is necessary to use an explosive that exerts its full force before the gases can give way, as in mudcapping rock. For that reason 50% to 60% ammonia or nitroglycerin dynamite is the explosive to use. Intermediate grades of soil usually can be depended on to hold the gases enough to permit the use of the slower 20% explosives.

The above does not mean that these grades of explosives are demanded for removing stumps. The fact is that stumps can be blasted out with almost any explosives manufactured; but the work can be done more economically and cheaply if the grades recommended above are used.



Four charges fired together tore this stump loose from its moorings and moved it six feet down the hill, but did not break it up. Another charge should have been located close under the center. It can be broken up easily now, however, by loading one cartridge charge down in the center of the hollow top. THIS STUMP IS A WHITE PINE, CUT 75 YEARS AGO.

The 20% explosives, especially the ammonia, leave the ground in better condition. A violent and quick-acting explosive tears out large holes in heavy ground, and packs the earth about the edges.

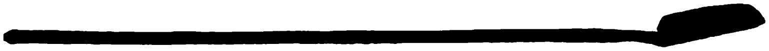
Time Required for and Cost of Blasting Stumps

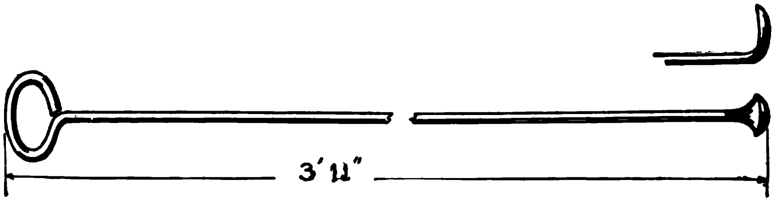
A day's work for one man is 30 to 60 average stumps blasted out. If three men can work as a crew, two making holes and one loading and firing, the number of stumps per man will be much increased.

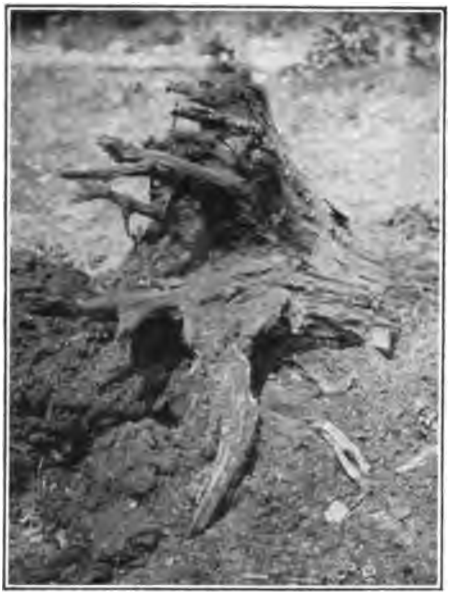
The cost of blasting stumps is a variable quantity. Those which blast out the cheapest are well-rotted oak or walnut, in moist clay soil. Probably the stumps which cost most to blast are green white pine or oak in dry sand. The skill and good judgment of the blaster also has much to do with the cost.

Tools

The tools you will need for blasting stumps are all common ones. The pictures show better what they are like than words can tell. You can use grubbing hoes, axes, crowbars for driving and for hand use, soil augers, long-shanked wood augers, wood tamping sticks, cap crimpers, water buckets, pocket







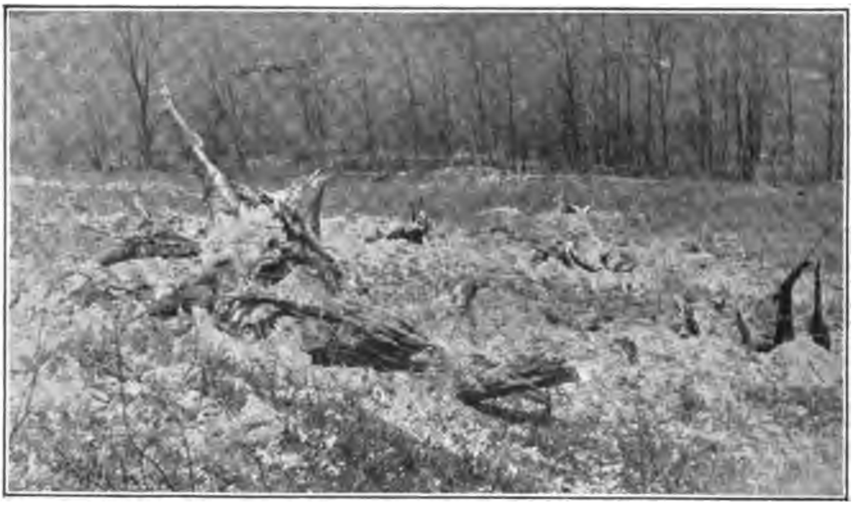
This stump came out as a result of a charge that was placed too deep and a little to one side of the proper position, and is not broken up for handling. It can be broken very easily as it lies, by locating a one cartridge mudcap charge between the two large roots seen in the picture. Had the original charge been a foot nearer the surface, the stump would have been broken in several pieces and all thrown out.

knives, steel probing rods, adzes, long-handled shovels, spade shovels, spoon shovels, scrapers, spoon bars, sledges and possibly other tools.

An old wood auger does not make a good soil auger, though it can be used in a pinch. For boring in ground an auger should have a leading point 2 or 3 inches long. Both wood and soil augers should have cutting bits that can be filed sharp a good many times without destroying them. Most blasting tools are supplied by all makers of explosives, and by hardware dealers. Some of them can be made at home, by your blacksmith.

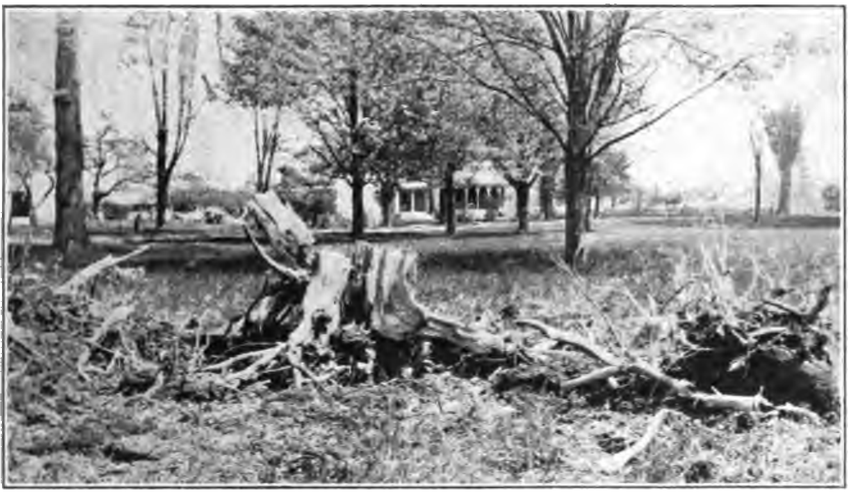
The spoon shovel and spoon bars are for tunneling and enlarging bore holes. Make them by turning up and trimming the edges of long-handled shovels. The probing rod is a piece of quarter-inch steel 6 feet long, with one end sharpened to a point. It had better have a handle turned over, or made into a ring. No long description of any of these tools will be given here, because farmers are familiar with them.

This bulletin strongly recommends electric firing for stump blasting whenever there is enough blasting to be done to justify the purchase of a blasting



A very old white pine stump blown out with three charges fired together electrically. The stump is well torn loose and cleaned, but another charge should have been placed at a point close to the wood under the center, to split the stump for easy handling.

machine. (See pages 159 and 160.) One to fire up to 10 charges can be obtained at a moderate cost. If skillfully handled its use will save its cost for each 500 pounds of explosive fired. Electric firing makes possible work in stump blasting that is superior to the work produced by any fuse firing when conditions are difficult. The several small explosives help one another.

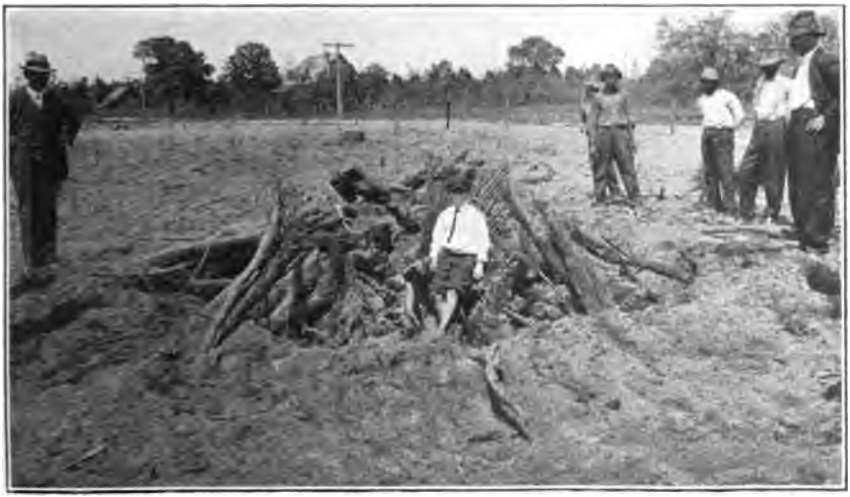


The blaster located his charges under this stump too far toward one side. The result is that the roots of the other side are left sticking in the ground and require another blast.

General Hints

To blast out standing trees, use about twenty per cent. more explosives than you would for the stumps. It is better to blast big trees with several charges, firing them electrically.

When big green stumps are blasted out with one charge placed under the



The result of an attempt to blast out a very large green stump with one charge. The explosives were located deep under the center, but they could not reach out far enough to tear loose the many firmly anchored roots. They blew off the top, instead. Such stumps should be blasted with three or more charges all fired together electrically.

center, some of the roots often break off high up, so that they interfere with plows. They are better blasted with several charges placed round the edges. If you are using a stump puller, split and loosen all the big stumps with explosives before pulling them.

It is more expensive to remove severely burned stumps than those with the tops intact. In blasting decayed stumps and those with no tops, fill the center cavity with ground and tamp it tight. Then place the charges in the usual way.

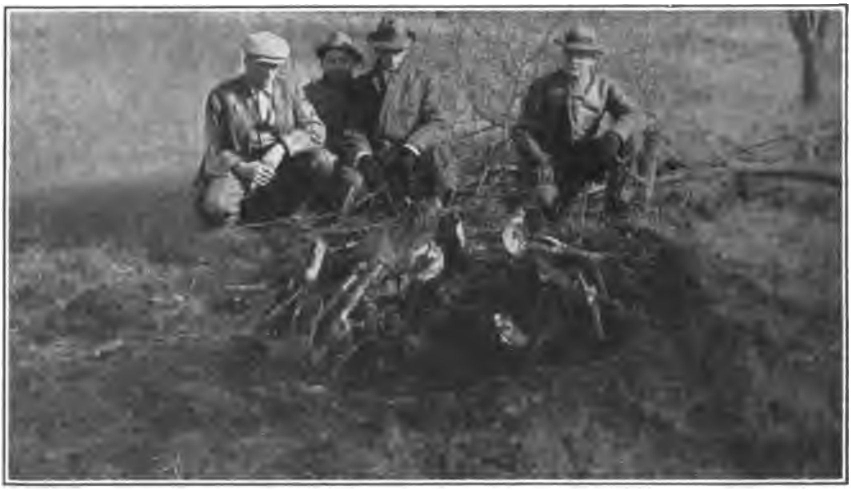
In blasting old rotten stumps that have sound roots, you often find the center underneath has rotted out, or become so that it is only a mass of punk. This material will not hold the gases of the explosives. To blast such stumps, better use an electric blasting machine, and several charges, or if fuse must be used, place the charges under the roots, or deep under the center, filling the hollow center with wet clay or loam.

Old logs and snags frequently are too big to haul or handle and to burn on clearings. Do not waste time cutting them in two, but smash them up with charges of about half a cartridge of explosives placed in an auger hole. If no auger is handy, put a heavier charge in a notch chopped in the log and cover with 6 inches of mud.

Fat pine tap-root stumps often may be shattered by charges of explosives placed in the top-roots, and the stumps left to dry. After a few weeks these stumps will burn like oil pots.

Many farmers can clear their land with very little loss of time from regular work by going about it in a systematic campaign. In an hour or two each evening a good many stumps can be blasted out and the work will be a pleasure. Only one man is needed. By making sure that the charges are rightly placed and proportioned to the stump, the roots all will be broken up so one man can handle them.

Headache Prevention Avoid working in the fumes and smoke of blasts, which will cause headache. Also keep the explosives from touching the skin of your hands, by wearing gloves.



When the charge is placed too shallow in the blasting of a stump that is newly cut or that has not rotted much, the top is ripped off, leaving many tight roots sticking high enough to catch a plow.

In removing saplings of sassafras and persimmon and stumps with long, tough roots that may sprout if permitted to break off in the ground, it often is of advantage to explode half cartridge charges a couple of feet under the trunks. This will not take out the trees, but will loosen the ground so that when they are pulled over in the usual way the roots all will come away.

Be careful not to miss charges that are placed, when you are lighting fuse or connecting wires. Get them all as you pass the stumps they are under. Unfired charges are liable to weakening and damage, and are sources of danger.

This is what the stump field should look like after the roots have been blown out. If the land is to be farmed, the next plowing should see every root removed.

Stump Disposal

Stumps make good fireplace wood and kindling wood. You likely can sell fireplace wood in nearby towns by doing a little advertising or inquiring of people you know. Pine stumps have won a place in the hearts of all American farmers as kindling wood. On nearly every farm and at nearly every home it pays to keep a large supply of pine roots for kindling. Don't destroy stumps when your wood-house is empty.

At many points roots can be sold as fuel for engines. In many parts of the South stumps can be sold for turpentine extraction. Everyone should make an effort to sell or to use his stumps rather than to destroy them. They represent real fuel value, and a little effort usually will get it out. The home kindling pile can be made big enough to last for years. The roots are ready-cut kindling of the best grade. As fireplace wood they are superior to top growth, because of mineral elements in the sap. They make as good fuel for lime kilns as any other wood. The price for home use near large cities often is upward of $8 to $12 a cord. For turpentine extraction the roots are worth at least $3.50 a cord. Farmers themselves can afford to pay at least $1.50 a cord, with the cost of hauling added, rather than to burn the stumps.

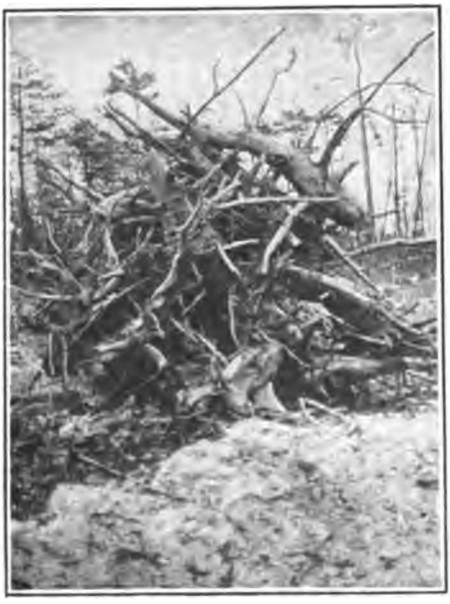
But when stumps cannot be sold or used they must be burned on the ground. Where they have been pulled out, without breaking up with explosives, and are large, the pulling engine or horses must be used to pile them, with the help of a derrick or gin-pole. An engine and a winch, using a cable, is a very good outfit for this purpose. A derrick may be a tripod with legs up to 40 to 45 feet long, or it may be a swinging boom derrick, with mast up to

Wood is a very expensive commodity in many parts of this country to-day. It never will get cheaper. Utilization of all parts of the trees that are cut down in land clearing is the thing to do whenever it is possible.

30 feet high and boom 25 feet long. Let the mast lean a little toward the pile of stumps, so the boom will swing round itself with its load. Another good machine is the Conrath portable piler, much used in Wisconsin. It requires 10 pieces of timber or poles, of which the largest, the two skids and the boom, are 20 to 22 feet long. A gin-pole may be any height that is convenient. An old dead tree makes a good one. Let it burn with the stumps piled about it. With 150 feet of half-inch cable and a pair of double blocks the piling can be done with horses.

A better way to handle stumps than with a derrick is to use small charges of explosives to break them up after they are pulled. When stumps are well blasted the problem of disposal is simple.

Start numerous small fires and haul and pile the roots on as they burn down. The fires can be kept going till all the roots are burned up, by putting on new roots and by shoving in butts. Have a wagon or sled and keep hauling and unloading all the time. Drive about the clearing on regular routes, each time making larger circles and throwing off a few roots as you pass by each fire. One man can clean up more acreage in this way in an equal time than several men working to pile the stumps in high piles with a derrick, except in cases where



The ideal size and kind of pile for burning stumps and roots. These piles can be built by hand, in unloading the stumps from a low wagon or sled. The fires can be started and more roots fed to keep them going.

the stumps are large and unbroken, or are left in very large pieces. What saves expense is piling by hand.

When you clear land by blasting, postpone all burning of brush, logs, etc., till after the stumps are blasted. Then have a grand burning of everything at once. But do not burn the surface—don't let the fire run over the ground. Keep it strictly to the boundaries of the piles. There is a whole lot of fertilizer in the layer of leaves, moss, twigs and other vegetable matter that every piece of cut-over or logged-off land has on the surface. It is foolishness to destroy this. Plow it down. It is worth a good many dollars on every acre.

When you burn a clearing, first get in touch with the fire warden of the district if there is any forested land at all near your place. Use every precaution to prevent the fire from getting out of your clearing and beyond your control.

Blasting Benefits Soil

You will hear—once in a long while—some man say that blasting out stumps hurts the soil. When you do, tell him he is mistaken. Proper blasting is beneficial to the soil. It is so beneficial that on thousands of farms subsoil blasting is regarded as a standard practice. In many orchard sections no one thinks of planting fruit or shade trees without first preparing the ground for them by blasting. There is a bulletin published on that subject which you should have if you are interested.

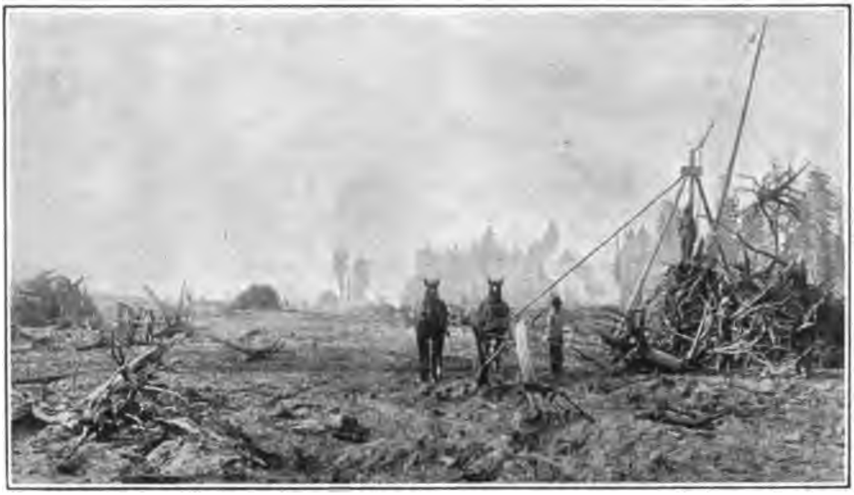
It is proper to add here, however, that when the ground is wet a blast does not produce the same effect in it as when it is dry. Subsoil blasting must be done when the ground is dry enough to crumble. Blasting a heavy soil that is in a plastic condition will make it more compact instead of loosening it. It is possible to do damage to a spot in a cultivated field by making a hole there—by digging out a stump, pulling a stump or blasting out a stump—and failing to fill it up level with the surrounding surface.

A good method of piling certain kinds of green roots. Piles even as large as this will prove to be more expensive than smaller piles in nearly every instance, and this method is justified only when stumps that do not burn well, such as green cypress, pine and fir, have to be burned quickly.

This bulletin states, correctly, that explosives take stumps out most efficiently when the ground is moist. While this is true, if you want to secure subsoiling benefit to the land at the same time you blast out stumps, you must do the work when the ground is at least reasonably dry. By blasting the stumps when the soil is not wet you sacrifice some of the efficiency of the explosives in the stump removing, and gain in fertility.

Clearing Sprouts

Don't allow the second growth to start at all. Pasture the land with what stock you have. To get goats especially for the purpose is practicable on large tracts, but the small tract had better be pastured by the cattle or hogs or sheep that the farm already has. Goat clearing is advisable only where time is plenty and money for development is scarce. Cut brush to the ground when it is in full leaf. Do the grubbing at intervals through the summer, as time permits. Remember that the grubbing must be deep to kill the roots—a foot down at least.



In this operation four men and five horses are used to pile the stumps. The gin-pole is a modification of the swinging boom derrick. The operation is rather expensive owing to its comparative inefficiency compared to hand-handling of the stumps when they are well broken.

After the stumps and sprouts are off the land, there still is some work to do before it is ready for crops. New land is fertile, but it usually needs lime.

Finishing Up New Lands

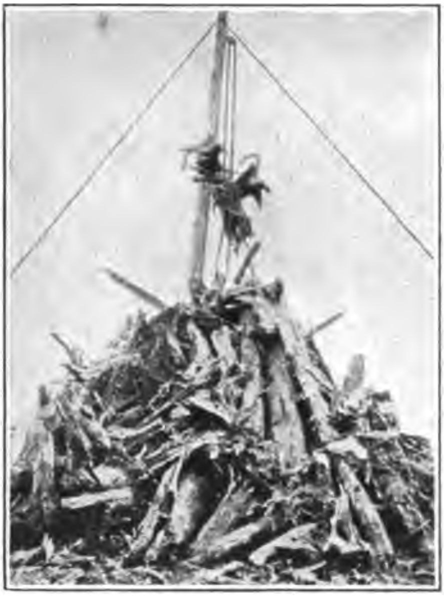
The unevenness and stump holes should be filled after the plowing is done. A small horse scraper is a valuable implement for this, but anything made like a King split-log road drag will do the work. Make a complete job of the leveling. Scrape the bumps into the hollows, and make the surface as even as possible, so that no water will stand in pools. This leveling should be done carefully in old cultivated fields as well as in new ground.

Crops for New Ground

To take full advantage of the big supply of plant food available in the soil of newly cleared land, you must plant crops that will bring in money. This may be a grain such as corn, but is more likely to be hay, cotton or fruit.

Strawberries are pre-eminently a new land crop. They never do as well on old land. If you have marketing facilities for them, put your new ground in strawberries for two or three years.

Potatoes are another paying crop on new land. Corn bears fairly well, but not much better than on old land. Other quick-bearing fruits, such as gooseberries, currants, raspberries and dewberries, do very well. Vegetables like tomatoes, sweet corn, watermelons, beets and squash, succeed very well. Oats is a very bad crop to plant because of the weeds it invariably helps to spring up.

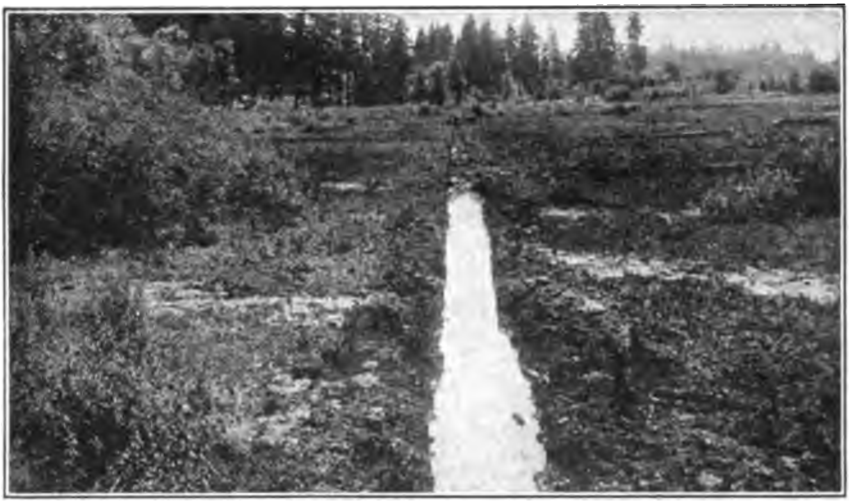


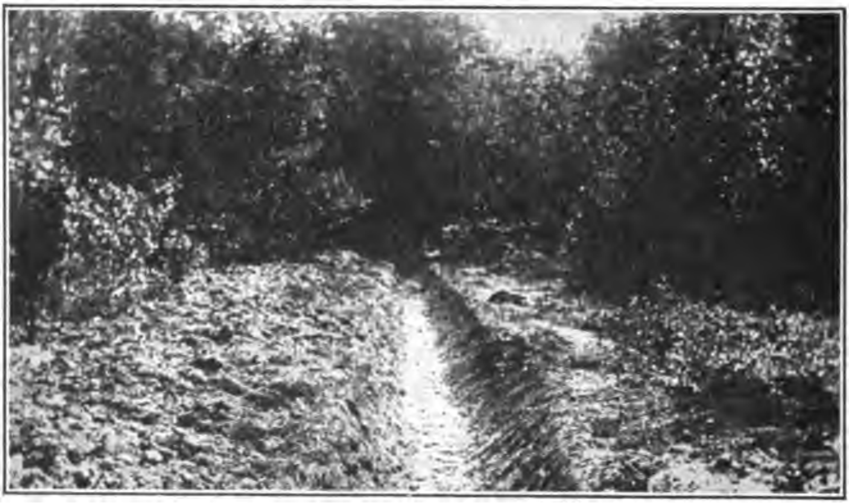
A type of "gin-pole" used to pile stumps for burning. Often piling by hand in small piles is much cheaper.

The hay crops are excellent, and in some of them there is a great deal of profit. Alfalfa is the best of them all. If you are planning to plant alfalfa, wait two years after clearing and plowing, meanwhile giving the land a heavy application of lime and cultivating it in some of the other crops named. All the clovers are good. Some people like to sow clover and timothy mixed.

On high land sow red clover and timothy; on low land alsike, timothy and red top grass. Soy beans, Canada field peas, field beans, cowpeas, mammoth clover and sweet clover, cotton and tobacco, all will yield enormous crops on new ground.

If you have cleared in the summer, harrow and disc at once, and sow rye, to be plowed down the next spring if you are going to cultivate the land, or to be mowed if you sow grass seed. The clover should be sowed on the surface of the ground just as the snow leaves in the spring. If you do not get a good stand from the first seeding, do not be satisfied with the poor one, but tear it up and seed over again. You cannot afford to let new ground loaf. There is money in making it work.





These ditches show the result of cutting the sod and the earth along the sides before the blasting. Shovel blades, axes and a hay-knife were used. A man cut a rod along one side in about two minutes. The blast left the soil outside of the cut firm and intact, while scooping the contents of the ditch out clean. (Upper, Miller Drainage District, Marion Co., Oregon; lower, Connecticut land of Polytechnic Institute of Brooklyn.)

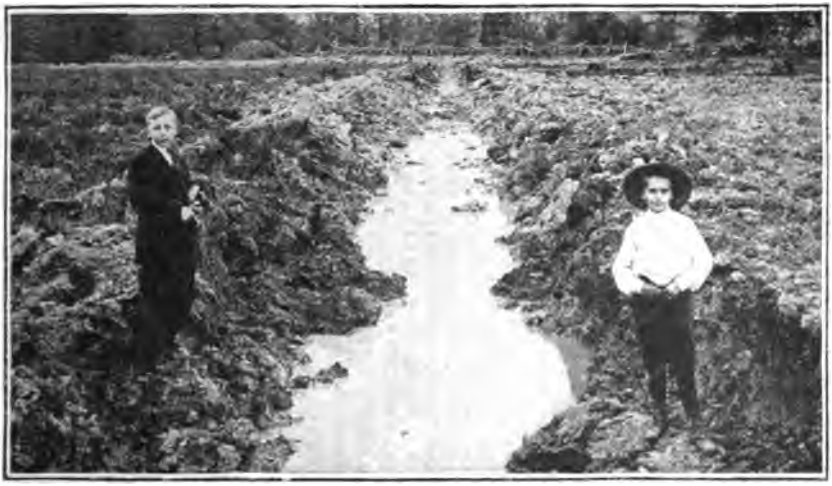
THE USE OF EXPLOSIVES IN MAKING DITCHES

The Matter of Farm Drainage

Much draining of agricultural land has been neglected because it has demanded so much money, time and hard work, and so many men. The excessive cost of ditching has retarded plans to drain, and poor methods have retarded actual construction.

In times past ditches have been made largely by hand shoveling. A few of them have been plowed out when shallow ditches could be made to do the work at all. But the digging of a few hundred yards of ditch 3 feet deep has been a summer's work on a farm, and the draining of land always has been very expensive and hard.

With the increase in the cost of labor, and the scarcity of farm help compared to the numbers of men that used to be available, there is serious need for means of draining that are easier, quicker and cheaper. Since ditching with explosives has become well known and generally practiced, it has come to be the desired method.



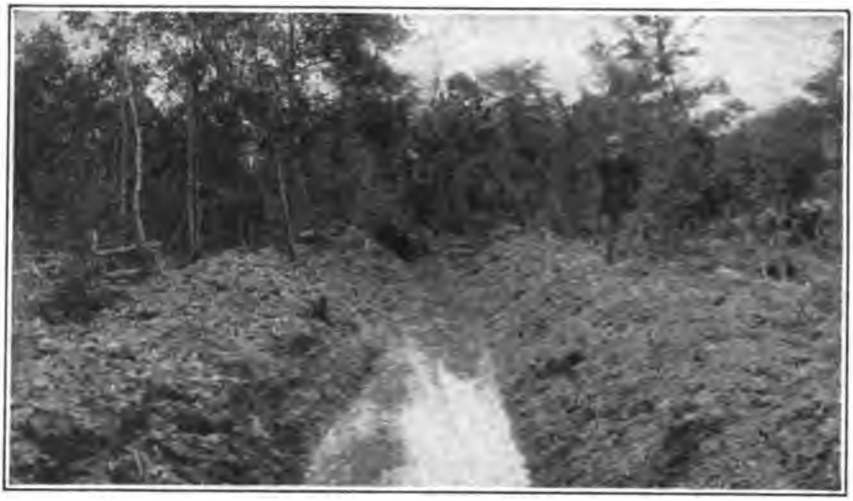
Observe the even spreading of excavated earth over the surrounding ground, leaving little elevated bank on the edges of the ditch. Even in heavy, stiff clay such as this, the explosion grinds the earth up pretty fine. (Chester Co., Pa.)

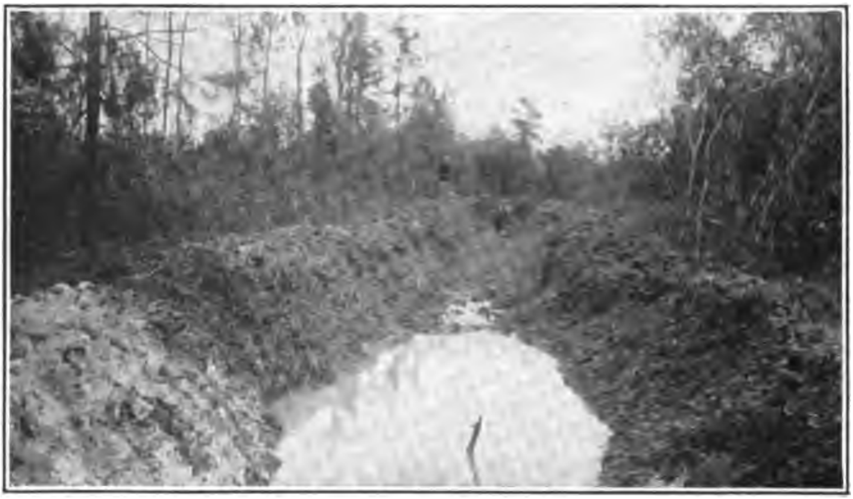
With few exceptions, ditches can be excavated with explosives anywhere. The nub of the whole matter lies in the fact that one of the cheapest ways of moving dirt known is with explosives.

To blast ditches practically all that is necessary is to punch lines of holes and push charges to the bottom. The sides and bottoms of the blasted ditches are not as smooth as if they were shoveled out, but they are even and true, and the flow of water soon levels them down and smooths the bottoms.

The work can be done quickly, neatly and with no expensive outfit. It calls for few men. A month's work by ordinary methods can be done in a day, or a week's work in an hour. Ditches can be blasted through any kind of ground except dry sand. The presence of brush, grass, stumps and stones is no bar to this method of cutting out the ditches, though of course they dig out smoother and cheaper when the nature of the ground is clean and clear.

As for size, ditches of almost any desired depth greater than 1½ feet and any ordinary width greater than 3½ feet can be blasted out. Ditches in fields





Representative blasted ditches in sandy loam of the Atlantic Coast section. In such material the charges must be heavy and must be skillfully placed to produce the perfect results shown. With proper care the excavation is satisfactory and the sides more even and true than in clay soils. (Charleston, S. C.)

and along roads, ponds, canals for drainage or boats, stream channels and similar cuts for any purpose can be blasted out.

This book explains the possibilities of blasting and makes clear the basis on which choice of a method for your work should rest. It shows how to plan and to lay out drainage systems, and how to construct open ditches to the best advantage. Other methods than blasting are recommended frankly when conditions and purposes are such that can be used to the best advantage.

Conditions Demanding Drainage

Two classes of farm land should be drained. One is the usual swamp land where the ground is saturated with water or at least is too wet for the growth of cultivated plants. The other class is land now cultivated, but which at some part of the year carries excess water.

The wet or damp lands may be merely low spots in fields, or may be entire valleys. Low spots often can be dried by cutting a ditch through rims of higher ground surrounding. If the wet condition is caused by overflow from streams, the stream channels should be deepened or widened till they carry all the water. If seepage from springs on the land or above it causes the trouble, a ditch cut across the flow of the seepage water will be the proper remedy. If the water-table is too high, a big open drain may gather and carry away the surplus, lowering the surface of the ground water to where it will not interfere with roots.

On account of the matter of moisture storage, as well as on account of general fertility, all land which is cultivated should be drained thoroughly of excess water. It is not enough to reduce the surplus to a point where meadow grass will grow; the drainage must be sufficient to dry off the ground soon after each rain and soon in the spring.

Roads always must be well drained if they are to remain solid and hold their shape in wet weather. Crooked streams should be straightened, to prevent cutting of the banks and overflowing, and ditches and streams too shallow or small to carry the volume of water present should be deepened or widened. Swamp conditions are a menace to health, breeding mosquitoes and their attending diseases. It often pays to drain lowlands where water stagnates, from the standpoint of health and comfort alone, when they are worthless for any agricultural purpose.

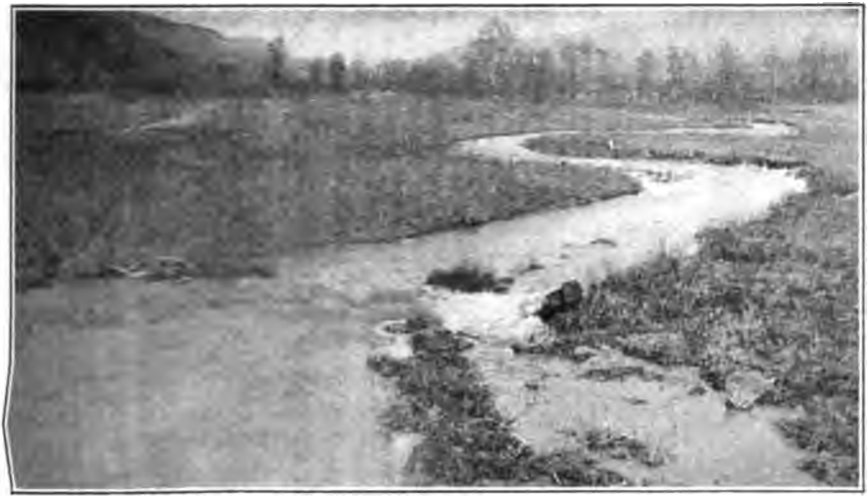
The Value of Drainage

Good drainage not only removes surplus water but actually helps to store moisture against dry weather. When soil is choked with water, deep rooting of plants or trees is impossible, and the soil processes which make available the plant food are hindered or altogether prevented. It is the absence of air almost as much as the presence of the water that does the damage. The better land is drained to a proper depth in each case, the finer and more mellow and crumbling it will be, and the more of useful moisture it will hold in the summer.

Swamp land usually is very fertile when the excess water is removed, and will grow wonderful crops. It contains a rich supply of plant food. Such land must be aerated—drained—and limed before its fertility can be used.

The direct loss of income from the idle acres in swamps can be figured by anyone. But this is not the only loss. There is the decreased net profit from other land that is farmed under the same ownership. The swamp land costs interest on its purchase price and taxes every year. This cost must be paid by the productive acres.

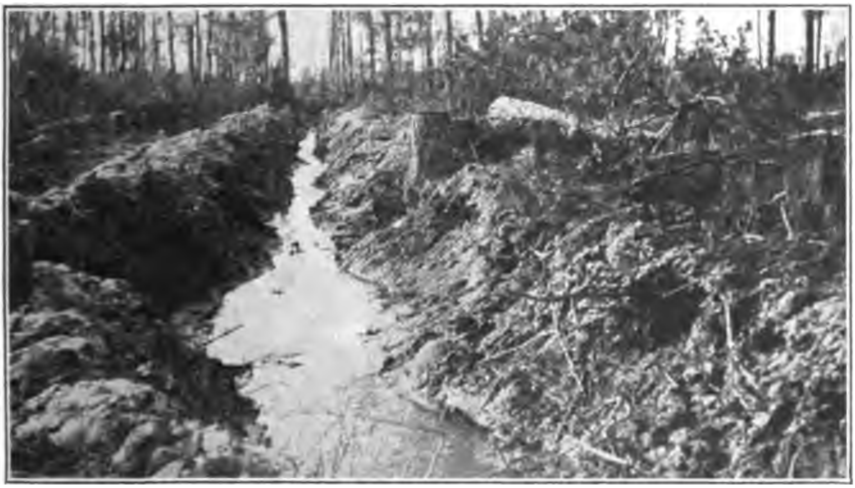
Two pictures that tell a story of swamp grass damming up a stream, which backs up and floods a field, ruining the hay, or corn or any other crop which may happen to be there. To dig out by hand or plow out such a clogged stream-bed is difficult and expensive, but to blast it out is the work of one man for an hour or so, at a comparatively small cost. (Mud Lick Farm, Julian, Center Co., Pa.)



Winding streams cut up and waste much land. They change their courses every year or so, tear away the banks at the curves, gouge out deep holes and build up sand bars. They occupy many times the area they would if straight, and practically ruin the soil which is worked over by the water. (Mud Lick Farm, Julian, Center Co., Pa.)

There is another feature of the matter that ordinarily is overlooked. This is the black eye which the farm is given by a ragged-looking piece of swamp land touching the clean acres. Whether the farm is on the market or is to be kept as a home, the waste lands cut down its value and damage its reputation among all who see it, including the stranger passing by, the neighbors over the fences and the man who lives on it.

It is a well-known fact that malaria disappears when mosquito bites are eliminated, and that the mosquitoes can be eliminated by draining the swamps.



The excavation done by a single line of charges of explosive properly placed in watersoaked clay soil is remarkable. The ditch resulting sometimes is two-thirds as deep as it is wide at the top. The bottom is U-shaped.

In the lowland sections of the country this has been done with great success. Even in the flat lands joining the ocean where tide water sometimes washes in over land and makes ponds, the opening out of channels has drained away the water and killed off the mosquitoes.

Other enemies that breed and lurk in swamps are weeds and predatory animals. The seed weeds in the swamps pollute all the surrounding land, and the cleaning up of the swamp is a favor and a benefit to the entire neighborhood.

Horses and cattle often get mired into the soft mud and are unable to get out without help. They may stick there and starve if not discovered and pulled out, or they may break a leg, or sprain themselves in their struggles.

One of the meanest things a farmer has to do is to haul loads of hay, grain, manure or fertilizer through a swampy place in the field. The remedy is to open a ditch through the center, after which the soft ground will harden up and the ditch can be bridged.

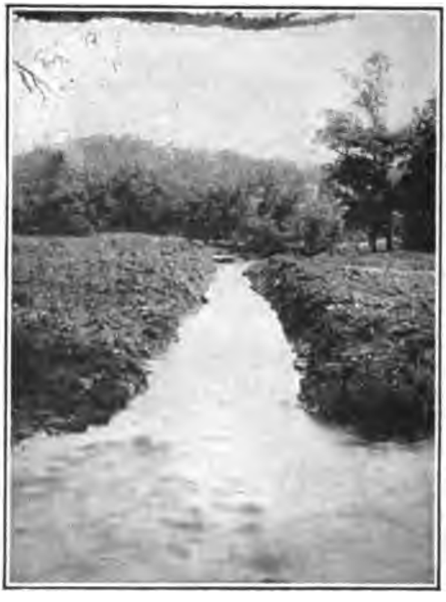
But not all wet land should be or can be drained. In general whether it will pay to drain or not will depend on how cheaply the job can be done, though this is such an indefinite rule that it is not of much value. Many a drainage job that can be done for $50 to $75 will add $100 to $200 to the value of a property. From a financial standpoint, a man is not justified in spending more money than the crops that can be grown will return in a reasonable number of years, though other considerations may make it wise to spend more.

The Essentials of Successful Ditching

It is well to have a clear idea of what to require of a ditch before attempting to complete the plans for it.

The successful drainage ditch should be straight, to give an even, swift flow of water without cutting out the banks or filling up the bottom. Its sides and bottom should be smooth and true, both to facilitate the flow and for appearance. It must be deep enough to put the water-table at a proper level. It must be wide enough to give the capacity required by the volume of water to be carried in flood times. The grade, of course, must be enough to carry the water away and to make the drainage action sure.

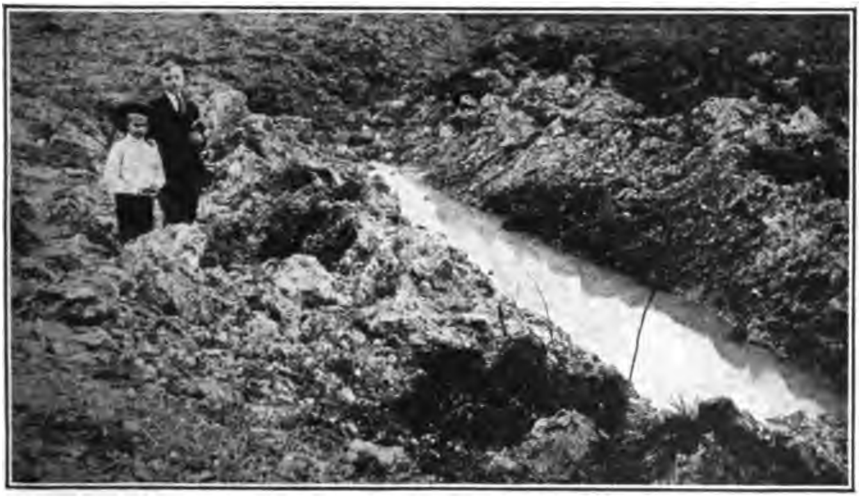
The excavated material ought to be well scattered and spread evenly over the surrounding land, without leaving a ridge or dyke along the sides of the ditch. When this material is piled up along the ditch it takes up ground space and acts as a dam for surface water and compacts the subsoil beneath by its weight, making the drainage of the fields much slower. Finally,



One of the best demonstrations of the value and success of the blasting of ditches is in cutting a large channel through difficult ground for a short distance, as this picture shows. One man can do the work in a couple of hours. The expense is not to be compared to the cost of cutting the same ditch by plowing, hand shoveling or machine work.

(Valley Creek, Pa.)

the ditch in respect to cost, time and men needed for construction, must come within the available limits. The cost must be low, the time of construction short, the men required few, and the work not unreasonably hard. Frequently if the ditching is to be done at all it must be by only two or three men in what practically amounts to spare time.



The line of the ditch follows the line of the charges faithfully, making true curves and angles. It should be the policy to eliminate all twists and to make the ditch as straight as a string whenever possible. (Chester Co., Pa.)

Nature of the Ground

The reasons why land is wet are few. There may be a layer of ground a few inches or a few feet under the surface, holding the water from escaping downward. The topsoil itself may be of such a nature as to prevent water from percolating through it. The water may keep rising from springs, producing the condition called seepage or spouty land. Again, the water-table, or height of the surface of a nearby large stream or lake or bay, may be nearly up to the surface of the ground, or the stream or ditch carrying away the water may be too small or too high at its mouth.

The nature of the ground must be considered in deciding on the method of ditching. Sand, for instance, is easiest to handle by some methods, and hardest by others. Dry ground handles cheapest in some ways and most expensively in others. In ditching you are likely to encounter hardpan, gravel of all sizes, both loose and in solid beds, and every kind of mixture of these materials. Each of these conditions calls for its own sort of treatment.

A ditch blasted through very dry ground without any side cutting. The result is not altogether a success, since the excavation is reduced in amount and is incomplete, and the cost is high. The soil is coarse sandy loam with much clay beneath. The blasting would have been much more successful if the ground had been full of water and the sides of the ditch cut before the blasting was done. (Near Snow Hill, Md.)

Heavy charging and skillful management will blast out a very good ditch through extremely difficult ground. Here the soil was matted with green roots. Some of them are left projecting into the ditch, but most of them are broken off and thrown out. The excavation of earth was very complete, owing to its watersoaked condition. (Georgia.)

Choosing a Method of Draining

The methods that are available for making ditches are:

Shoveling by hand,
Plowing,
Trenching with machine equipped for excavating,
Blasting.

Each method has its place. In choosing a method many considerations enter into a wise decision. The purpose for which the ditch is made—whether open ditch or underdrain, canal for water or boats, and the like, must determine the character of the ditch. The kind of soil, the size of the ditch, the amount and kind of obstructions, the time available before the job must be finished, the men that can be put on the job, the capital available for labor and equipment, the source of the water to be drained away, the height of the water-table, the use of the land to be drained, the amount of water to be carried and the fall of the land—all these factors have a bearing on the selection of the method of making a ditch.

Note the projecting knobs of earth held by matted roots of trees and brush. Such irregularities in the sides of a ditch are not a disadvantage except in appearance in a ditch where the flow of water is heavy and swift. But when the volume of water is small and the fall slight the edges should be smooth and straight.

Tile Drains

No open ditch through cultivated land should be considered when conditions are such as to make underdrains better, and when money is available for constructing them.

But in a great many places the nature of the ground or water flow is such as to require open ditches. In other places they are just as good as closed drains. For instance, through pasture land and woods an open ditch will do just as well as an underdrain and better where there is a spring or brook which overflows at times. In muck land closed drains are not practicable.

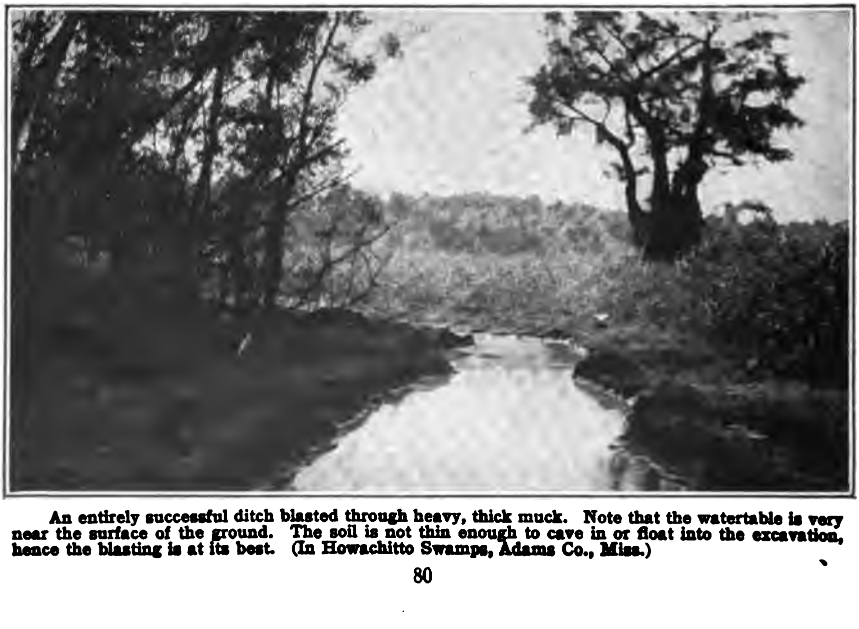
Ditches for immediate laying of tile cannot be blasted out with satisfaction; the bottoms are left too soft to hold the pipe properly. If funds for tile draining are not available immediately, an open ditch can be made by blasting which, after a couple of years, will be entirely satisfactory for tiling, though

Proper blasting will open a channel through thick brush and grass, though such a ditch will not measure nearly so much in the clear as though the land was clean and free from roots. You can blast channels for boats or for drainage through a marsh where the ground is under water. (Kentucky.)

the earth required to refill the ditch will be scattered widely. Light blasting very often is desirable, however, to loosen hard ground in order to make digging of tile ditches by other methods easier.

Open Ditches

Large ditches and canals, 15 feet wide or more, and miles in length, often justify the use of a floating dredge. Those who are interested in methods of trenching for underdrains, and in excavating machinery, floating dredges, ditching plows and the like, should get Farmers' Bulletin 698 of the U. S. Department of Agriculture. It goes into the subject in detail.



An entirely successful ditch blasted through heavy, thick muck. Note that the watertable is very near the surface of the ground. The soil is not thin enough to cave in or float into the excavation, hence the blasting is at its best. (In Howachitto Swamps, Adams Co., Miss.)

What can be done by blasting in sand. This big ditch was made with explosives near Pinellas, Florida. The conditions are about the most unfavorable under which it is possible to blast out ditches. Heavy charging and electric firing were required here.

When many stones, roots and stumps are present, a dredge, or in fact any excavating machinery, cannot be used to advantage or at all. Ditches less than 2 feet deep can be plowed out cheaply, using two or four horses hitched by means of a chain to a plow of some kind. Another implement that is effective for making very shallow ditches is a scraper, either with or without wheels. A road machine or scraper is about as good as any. The trouble with these machines is that they will work little more than to a depth of a foot, and are expensive. Their advantages are that they scrape the dirt well back from the edge of the ditches and make an even, clean-looking job by machinery instead of by hand.

When tile is to be laid in hand-dug trenches, begin the spade work in the bottom of a plow furrow. By running the plow twice in the same place you can make the furrow nearly 12 inches deep.

Blasting of ditches is discussed under a separate heading.

Possibilities and Limits of Blasting

The blasting method can be used for making almost any open ditches. A blasted ditch made with one line of charges usually is about twice as wide

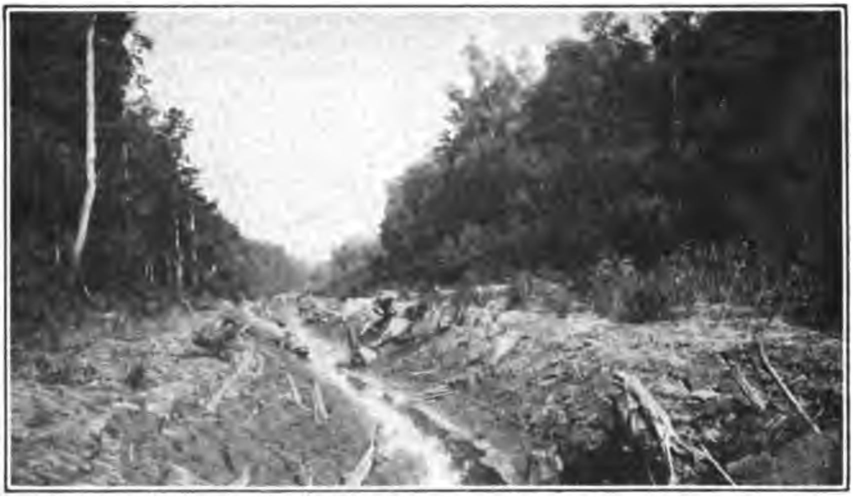
Blasting makes the cleanest and smoothest job in sandy loam that is saturated with water nearly to the surface. Note how cleanly the edges of this ditch are cut. Also note that no excavated earth was thrown to the right of the ditch, in the picture. A strong wind carried it all over to the left side.

at the top as it is deep. The sides and bottom are fairly even. The dirt is spread out widely without leaving ridges down the sides. Ditches can be blasted successfully in clay, loams, gravel, thick muck, peat, and, in fact, every sort of earth except very thin muck and dry sand. Ditches can be blasted through sand when saturated with water.

It is easier to state the limitations of the blasting method than its possibilities. As stated above, you cannot blast ditches through dry sand. Thin muck runs into the excavated channels. In any ground where there are many roots of trees or brush, the sides of the blasted ditch will be ragged unless the roots are cut beforehand along the sides. In blasting through heavy sod, the sod sometimes folds back without tearing loose, or else simply flops back down into the ditch—unless the edges are cut before the blast.

These are the limitations of blasting, and there is a way to overcome each of them except that of thin muck. The fact is that the way explosives will cut out a narrow channel is really wonderful. Those who have not seen the blasting of a ditch can have no idea of the efficiency of the work of explosives for this purpose or of the clean and finished job they do.

Explosives work to the best advantage when the ground is wet—in fact in thin mud. It takes less explosive to throw out a required sized ditch, or the same amount of explosive will make a bigger ditch, when the ground is thoroughly wet than when it is only damp or is dry. The blasting may be done with perfect satisfaction through ground that is so soft that there is no footing for horses and no support for wheels. In fact, it can be done when the surface of the ground is under water.



A big ditch blasted through a swamp where the muck was almost too thin. The sides of the ditch moved in a little, but stopped as the water left them and they dried a little. Blasting is very effective in muck, so long as the material is not so thin that it moves in and closes the excavation later. (Gilliard's Lake outlet to Mississippi River, through Howachitto Swamp, Adams Co., Miss.)

Excessively soft ground, stones, stumps and roots are the things that make ditching by hand or by machinery costly and difficult, if not impossible. But they interfere with blasting very little and raise the cost only slightly. Blasting of ditches can be done in dry ground of a heavy nature. The general rule is that the wetter the soil, down to the thin muck stage, the better and cheaper the blasted ditch.

It is possible to blast out a good ditch through almost pure sand, as this ditch shows, provided the ground is full of water and the operator understands his business well.

About the smallest ditch it is worth while to blast is 1½ feet deep and 3½ feet wide. From this size up to 6 or 8 feet deep and 18 or more feet wide the use of explosives has advantages over almost any other method under favorable conditions. But in general the efficiency of the blasting method falls off after the depth is greater than 6 feet and the width greater than 18 feet. For long ditches a floating dredge will be economical. Small ponds may be dug by blasting.

In blasting ditches two or three men can do the work of a great many. They can accomplish in a day or two what would take them months to do by hand.

Laying Out the Ditch

The size or capacity of ditch required, the grades, the depth and the lines should receive careful attention. When there is considerable length of ditch or considerable acreage to be drained it is wise to employ a drainage engineer or a professional surveyor in getting the grades and in determining capacity. Except in very large operations the matter of depth and location of the lines of drains is largely one for farmers themselves to decide, because they know the requirements of the different soils and of farm operations, as well as have had the chance of observing the flow of flood water.

The eye is not to be depended on in determining the fall of a piece of land that is nearly flat. Use a level. One way of using it is to drive a post at the upper side and fasten to this, by nailing or bolting, a crosspiece with a straight edge up. Then lay a level on the straight edge and make it absolutely level. The crosspiece should point directly toward the lower side of the piece of land

In big drainage projects where large canals must be made the blasting method often proves economical. There is no doubt that explosives will do the excavating, as this picture shows. Labor cost and complications are reduced to a minimum on account of the few men and short time required for the blasting.

to be drained, where a helper must stand, holding a marker which he raises or lowers on a pole. Sight over the straight edge and have him elevate the marker till it is on a true level with your crosspiece. The difference between your distance down to normal ground surface or normal water surface, and his, will be the fall.

This ditch is a good instance of the speed and efficiency of the blasting of ditches. Three men made it complete, as the picture shows—1000 feet long—in 5 days. About 400 pounds of explosive was used. Much cutting of roots and sod was required. (The Hart E. Hutchens Co., New Brita'n, Conn.)

An "A" frame or any other support for the level will do if it will hold the level steady. Sights for attaching to the level can be bought of almost any hardware store. They are as accurate as rifle sights. Tripods for holding the level also are made and can be had at most hardware stores. The plain level is not very accurate. If you do not use sights, repeat the sighting two or three times to make certain of the finding.

Grade, Fall and Line of Ditch

A fall of one inch to each hundred feet is enough to carry off excess water from a field in most cases. This is for straight ditches. If the ditch line is to swing here and there, an inch of fall is hardly a sufficient allowance.

Part of a half mile of ditch blasted out complete, with no work in preparation or finishing ground. The ground was full of water, and transmitted detonation was made use of to fire the charges in about 200-foot sections. Note that the line of the ditch is true, the edges fairly even and smooth, and the earth well scattered.

The appearance of grade is deceiving. Few pieces of ground are so flat they cannot be drained. Watch the land when it is flooded and the water is going down. Set some stakes then to indicate its level and its channels. If a small stream flows through the land, the line of sight should not follow its wandering course. The total fall should be determined from just two positions—one where the stream enters and one where it leaves.

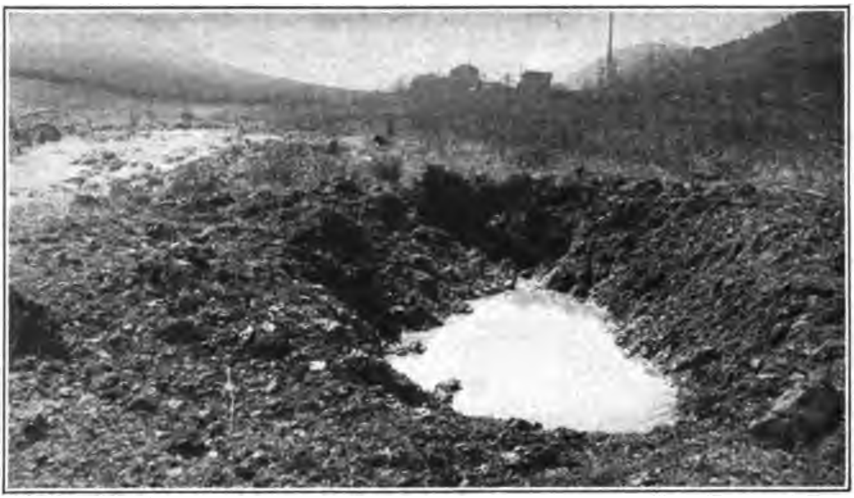
The flow of the flood water is a good guide in locating the proper line for a ditch. This is the natural line of drainage. If nothing else interferes, place the ditch in this position. The idea is to have it as near as possible to a straight line and as short as possible. But avoid cutting fields with open ditches when possible.

Determining Ditch Depth

The one important factor to consider in determining how deep a ditch should be is the proper height of the water-table in the ground. This is the level of the water that will stand in a well or hole dug in the wettest part of the field. The water should be at least 4 or 5 feet below the surface in ordinary heavy loam or clay, and 1 to 1½ feet in muck.

The deeper a ditch is the farther and more thoroughly it will drain land. Your calculations as to how far you can rely on one ditch to gather water and to effect the drainage of ground must be based on this matter of the depth of the ditch. The nature of the ground has a good deal to do with it, particularly with the rapidity of the drainage. A loose, open gravel will drain out nicely in a few days, and a tight stiff clay will take weeks. Naturally the ditches should be closer together in the clay than in the gravel. Other soils can be judged from these.

The depth must not be more than the water-level at the mouth of the



The first shot (of 12 charges) of a ditching operation. Note particularly how abrupt and clean-cut the end is. The last charge lifted its load fully and cleaned out the ditch in good shape. The next one placed beyond will continue the excavation just as well. (Mud Lick Farm, Julian, Center Co., Pa.)

ditch or drain. This is a governing factor in many places. When a ditch empties in a stream you often can carry the channel farther down and secure a lower level if it is needed; or the stream itself may be deepened.

Determining Width of Ditch

The water carrying capacity of a ditch is most largely governed by its width. Often the narrowest ditch that can be made will have more capacity than is needed to carry all the water there is. The bottom should not be wide, but should be narrow, almost like a broad V, because the amount of water to be carried at low water stage is small and it should be confined closer to make it flow better. In flood times the water will rise higher and will make a broader stream.

This ditch is 5 feet wide and 3 feet deep. It was blasted out with one row of charges placed 18 inches apart, each charge consisting of one cartridge of powder. About 100 feet of the ditch was excavated at each explosion.

Where large swamps are to be drained, or the flow from larger springs is to be carried away, a ditch of minimum width sometimes is not big enough. If you can calculate the volume of water to be carried away, you then can figure the correct width for your ditch. Measure the flow per minute in cubic feet at some outlet. Or measure the amount of standing water by getting its depth and extent. Provide ditch enough to pass the volume present in the required time. In any case the ditch should be big enough to clear away the water of a 2 or 3 days' rain shortly after it stops coming down, and to take care of spring floods.

How to Make Ditches by Blasting

Description of Blasted Ditch

Ditches are blasted by loading suitable charges in holes made in a row or line. Each charge of explosive properly placed for ditch blasting will blow out, roughly stated, a crater which is half to three-quarters as deep as it is wide. Nearly all the dirt is thrown out. Most of it is lifted to a height of about 200 feet in the air, requiring some seconds before it returns to the ground.

The sides and bottom of blasted ditches have 6 to 12 inches of loose dirt, which can be left where it is if the ditch is big enough in the clear, or can be taken out easily and cheaply by shoveling or

In these ditches the excavation of earth was satisfactory, but the number of roots was so great that the result as a whole is not what it should be. No side-cutting was done before blasting. If there had been, the resulting ditch would have been smooth, straight and deep. In blasting through brush and timber, the long, sharp shovel blade, the hay-knife and the axe are necessary tools. (S. Chester Coursey, Hayden, Md.)

with light horse scrapers if a larger ditch is wanted. Good blasting practice will so load the charges that the ditch as cleaned out by the blast will be big enough in the clear and will require very little, if any, hand finishing.

Firing Charges

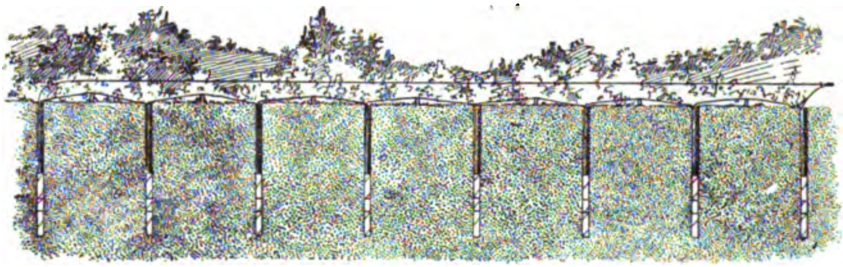
One of the first things that must be considered when planning to make a ditch by blasting is the method of firing the charges of explosive. Most of the rest of the operation hinges on the firing so much that this matter must be determined before even buying the explosive.

The standard practice is to fire all charges electrically, as will be described immediately following. This method is sure in results under any conditions. Ordinary cap-and-fuse firing cannot be used successfully in ditching, except by the transmitted detonation method in which the center charge only is set off by a cap, the rest being fired by shock transmitted through the ground. This method is fully explained on pages 89 to 92.

General Method of Firing

Ditches can be blasted through any sort of ground except dry sand when the charges are fired in this way. The procedure is as follows:

The charges are prepared for loading, with electric blasting caps, in the manner described on pages 150 and 151. Prime each charge. Holes are made in the ground on the ditch line and the charges are loaded as described in following pages.



Typical loading of ditch blast for straight electrical firing of all charges for 3½' x 7' ditch.

The holes or charges should be spaced 30 to 40 inches, and where very heavy charges are used, as much as 50 or 60 inches apart. They must be close enough together so that all the earth between each two will be thrown out clean, leaving no ridges in the bottom of ditch. Thirty inches ought to be close enough under any conditions of soil and size of charge. The only way of determining definitely just how far apart the charges should be is to make test shots, as suggested on page 98, in the discussion of amount of explosive required for charges. As many charges should be loaded as your electric current can fire.

The actual firing is done by connecting the wires of all the charges and sending an electric current through them. An electric blasting machine should be used to supply current, though power or light current can be used. A full discussion of the details of how to connect wires and to fire, is contained in the special chapter on the subject in the latter part of this bulletin.

You can fire as many charges as your blasting machine will handle. The machines are made in different sizes, to fire 3 to 150 charges at once. Procure a large machine if you have miles of ditch to blast, but if you have only a few hundred yards, a 30-charge machine is big enough.

The proper explosive for blasting ditches by this method depends somewhat on the soil. In all clay and heavy soils use 20% ammonia dynamite, and for large ditches use 30% or 40% ammonia dynamite except when the work is under water. (See page 154.) In blasting ditches in wet sand or other light ground use 50% nitroglycerin dynamite. Where charges must remain under water more than half an hour, use nitroglycerin explosives only, for ammonia explosives will deteriorate if soaked for excessive periods of time. It is well to use a low-freezing grade of the explosive at any time of the year, since this guards against chilling, and insures a more thorough detonation of the explosive by the blasting cap.

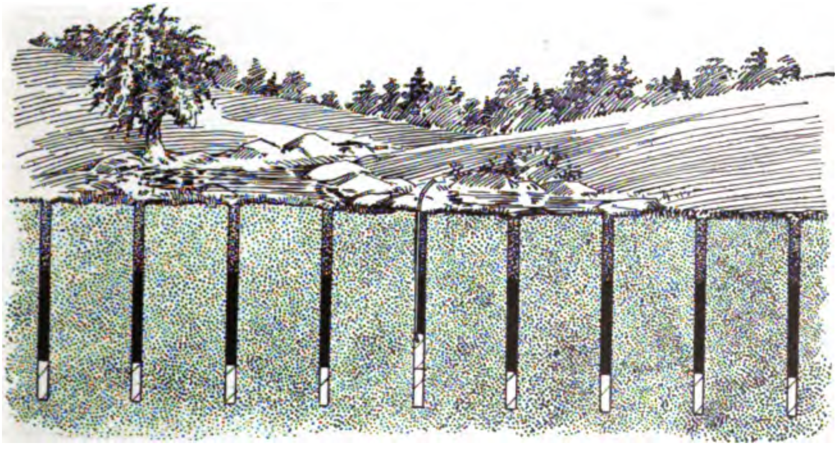
Electric blasting caps, connecting wire, leading wire and blasting machine with the other tools needed for loading, are the supplies demanded for ditch blasting by this method.

Depth for holes, amount of explosives per charge and many other details of the loading are discussed on pages 95 and 97.

Transmitted Firing

When the ditch is to be blasted through ground that is saturated with water, the method of transmitted firing often can be used to advantage. In order to insure its complete and unquestioned success, the water must cover the charges and had better rise in the holes nearly to the surface of the ground.

Under such conditions transmitted detonation can be expected to succeed even in sandy ground and gravel. It is in muck and clay fully saturated with water that the method is most successful.



Showing typical loading of transmitted detonation ditch blast--fuse firing--for 3½' x 7' ditch.

Transmitted firing is made possible by the fact that high explosives can be fired by shock (as by that given by a cap, for instance). Under the conditions of soil described above and of proper loading, the shock of the explosion of one charge will travel through the ground and water with enough force to fire the next charge, and so on down the line. So rapidly does this take place that in a line of charges hundreds of feet long you cannot see any difference in time between the middle and end explosions.

If cartridges of explosive are laid on a plank a foot apart and one of them is fired with a cap and fuse or otherwise, the others likely will be exploded by the influence projected through the air. In actual ditching work the shock of one charge cannot be depended on to travel through the ground strongly enough to bring about full and complete detonation more than a couple of feet.

The usual distance apart that is best for charges to be fired by transmitted detonation is 15 to 20 inches. The exact distance in any particular soil at any time must be determined by test shots. Try a shot of 8 or 10 charges (of the amount of dynamite and at the depth of loading required, as explained on pages 97 and 98, spaced 12, 15, 18, 20, 22, and 26 inches apart.

Spacing of Charges

Careful observation of the blast resulting will show the point beyond which charges fail to explode or explode weakly. The correct spacing of charges, to insure full detonation, will be about two-thirds of this limit.

One charge may fire another at a greater distance than is economical, because it merely may explode it weakly, without developing anything like the full force and speed. And on top of that, each weaker explosion sends a still weaker one on to the next charge, till a point is reached a few charges away where the shock transmitted is not enough to bring about firing at all.

This weakening of the transmitted shock is important, because the strength of an explosion of dynamite depends on the severity of the shock which fires it. For illustration, and not that these figures bear any relation to the true amount of force, if the first charge, the one fired with a cap, gives off 10 pounds of energy in the form of a shock, and this 10 pounds is diminished to 8 pounds by the time it reaches the next charge, this second charge will not detonate with quite 10 pounds of shock energy. It may have only 9 or 8. And in turn, the shock energy from it will be diminished to 6 or 7 on reaching the third charge. If the particular kind of explosive used requires a full 6 pounds of shock to detonate it completely, the transmitted method of firing is going to fail. Even of those charges which do explode, half will give much less than their full force.

Water is not elastic, but air is, and dry soil is and absorbs shock because it contains a good deal of air. The gases of an explosion drive water-soaked

When roots and sod are not cut along the sides of the ditch before the blasting, the edges are never as smooth and as straight as with cutting. An effort was made to trim this ditch up after the blast. It carries water about as well, but it doesn't look to be as good. (In Miller Drainage District, Marion Co., Oregon.)

ground as a steel rod can be driven by a hammer. In it there is but little "give," hence the shock travels with a minimum of loss in force. In dry ground the air cushions the blow of the gases and eases them to a standstill within a short distance. Clay is more solid than sand, and this explains why transmitted detonation works better in heavy soils than in light ones.

The nature of the ground and the amount of water present therefore largely govern the spacing of charges, though a large charge of course will throw a shock slightly farther than a small one.

As will be seen from foregoing named facts, the effects of lack of water and of light, spongy or sandy ground, can be counteracted somewhat by setting charges closer together. When necessary it is practicable to put them only a foot apart. To put them closer, however, is not practicable, for it costs too much. On the other hand, when the charges are heavier than ordinary—say of two cartridges or more—in wet, heavy ground, they may be spaced up to 26 inches apart with satisfaction.

Temperature of Ground

Temperature influences transmitted detonation only by reason of the fact that explosives are less sensitive to shock, and harder to fire when cold than when warm. All grades explode easiest when at a temperature of 70 to 80 degrees. Straight nitroglycerin dynamite must be used at a temperature of higher than 50 degrees. It is not well, for many reasons, to attempt to fire too many charges at once. Several hundred can be fired successfully sometimes, but the usual limit had better be 50 to 60.

When the nature of the ground, amount of water present or temperature are not of the best for securing transmitted detonation, matters may sometimes be helped by taking advantage of the fact that blasting caps are much more sensitive to shock than the explosive itself. Place a common blasting cap, without a fuse, but with the open end filled with tallow, every 25 to 50 feet. These caps may help to restore the diminished force of explosion, making satisfactory detonation extend much farther than it would without them.

A ditch 10 feet wide and 5 feet deep through newly cleared land. The extra width of the excavation helped to tear entirely loose and throw out stumps and roots, leaving the edges comparatively clean of projecting roots. Under such conditions finishing the ditch after blasting is better than to try to cut the edges before. (Paragould, Ark.)

Stones, roots and old logs interfere with transmitted detonation. When these are located in the line of the ditch it is necessary to fire charges on both sides of them as at the beginning. Pay careful attention to changes in soil as you work along the ditch line. It may be necessary to shorten the spacing, or, again, it may be possible to lengthen it and save money.

The firing of the line of charges by the transmitted detonation method is done by loading the required number of charges without priming or with caps and no fuse as described above, all except the center charge of the row. In it place a double charge of explosive, or at least an extra cartridge of explosive, primed with cap and fuse or with electric blasting cap. Fire this charge in the usual way.

Prime Center Charge

Sometimes an electric blasting cap placed at each end as well as at the middle of the line will fire difficult charges successfully. Once in a while the electric blasting caps may be needed even closer—say every 3 to 5 charges.

The Explosive to Use

The proper explosive for transmitted firing ditch blasting is nitroglycerin dynamite of 50% strength—either regular or low-freezing. The 20% strength dynamites recommended for electrical firing cannot be used at all under this method, because they are not sensitive enough.

Summary of Firing Facts

Transmitted firing requires only the explosive itself, and a cap and some fuse for each couple of hundred feet of ditch, while electrical firing requires wiring, an electric blasting cap for each charge and a blasting machine or other source of current. This advantage of the former method very often is offset, however, by the fact that it requires nearly twice as many holes as electric firing. It is easier to load two cartridges in one hole than to make two holes. In addition, electric firing always can be depended on for the desired results, while transmitted firing will succeed only when the ground is full of water. As for quantity of explosive required by each method to excavate any certain ditch where either can be used: In theory the two methods require about the same. In practice, however, more will be used in transmitted firing, unless the work is done very skillfully. The saving in the use of this method comes largely from a saving of electric blasting caps and time, and the need for little equipment.

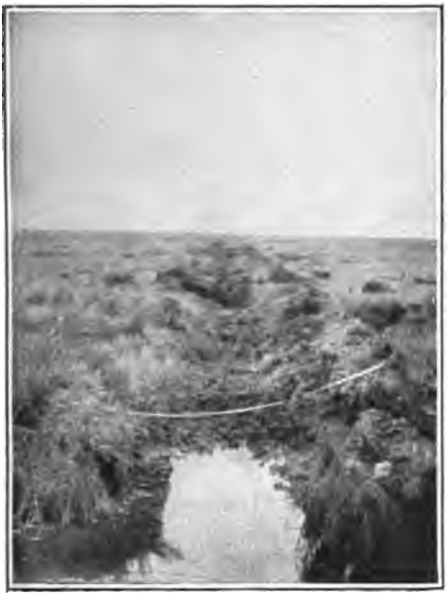
Preparation of Ground and Loading

Cutting Roots and Sod

During the early days of ditch blasting, before experiments had standardized practices, much objection was taken to the ragged edges of ditches blasted through sod and through brush and woods. The sod would not tear loose and fly away from the ditch. It would either fold back and make a ridge along the ditch, or it would flop back into the ditch after the dirt beneath had blown out. The remedy is to cut the sod and roots along the edges of ditch before blasting.

When there is sod, two furrows should be plowed along the ditch line—one at each edge. Another plan is to cut along the sides of the ditch-to-be with a spade, axe or hay knife. In case the line of the ditch runs past trees, or through brush or forest land, the roots should be cut on both sides the ditch. An axe is needed for the big roots. Where there are many roots the ground should be cut 18 inches deep.

Make the cut at the angle the side of the ditch should have, say about 45 degrees. The blast will clean out the dirt to the cuts and will leave the wall on the outside firm and intact. Cutting the edges of the ditch saves trouble and work after blasting. It insures that the sides and edges of the ditch will be as straight as though the ditch was shoveled by hand or plowed. But it should not be understood that ditches cannot be blasted without cutting the ground. Except through extremely heavy sod and roots, explosives used alone will clean out good channels when loading and firing are done properly. The cutting of the edges simply makes a smoother, more complete job.



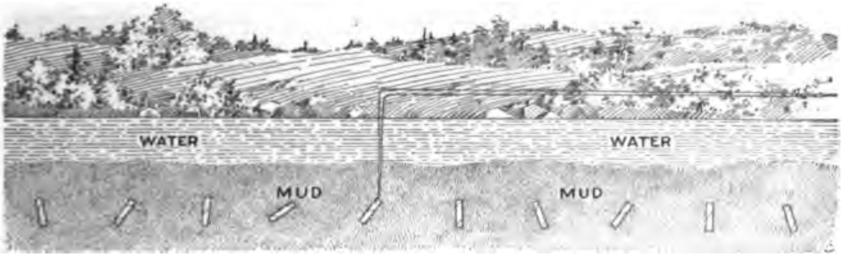
A typical instance of what results from an attempt to blast a ditch through heavy sod without first cutting the sides. The sod breaks loose in the middle of the ditch and either folds back without tearing loose or falls back into the ditch after the dirt beneath it has been swept away. Such ground should be thoroughly watersoaked and the edges of the ditch cut with shovels or hay-knife, or at least by plowing furrows. (Virginia.)

Locating Line For Holes

The charges should be placed along the center line of the proposed ditch, except where the ground is harder, or higher at one side than at the other, when they should be placed 6 to 12 inches from the center toward that side. The eye is not capable of keeping the line of charges true. Stretch a string where they should go. In making the holes the man should have a measuring stick to space them accurately. Guesswork on this point is likely to be expensive.

Make the holes straight down into the ground.

It is much easier to make holes in soggy ground than in dry ground. In fact, it is almost impossible to sledge down a bar in some dry ground. When there are no stones, a soil auger often is of advantage, though the bar and sledge are hard to beat for speed and results. Modification of the up-and-down position of the cartridges or charges is desirable only when you are deepening ditches already made, with bottoms of thin mud or thick muck. In such material you need punch no holes. Just push the cartridges into place down in the mud with your hand and place them in a horizontal position lengthways of the ditch.



Typical loading for deepening ditch with bottom of mud—electrical firing of center charge for transmitted detonation.

Preventing Dirt Falling into Ditch

If you have a windy day for the blasting, with the air drawing strongly across the line of the ditch, you will be surprised to see how far the falling dirt will be carried away from the ditch during the few seconds it is in the air. On a quiet day, 6 to 12 inches of dirt will fall back into the ditch. On a windy day your finished ditch will be several inches deeper and wider than on a calm day. Do not take from this that a windy day is demanded for satisfactory results. The force of the blast spreads and scatters all but a little of the dirt. The wind merely helps.

When water covers the charges, be sure to make the primed cartridges, and the cap and fuse, waterproof with tallow or paraffine at points where they join. Tar and thin lubricating grease are very poor materials for waterproofing.

An explosion throws the earth so high that the slight additional depth or height of sides met with in deepening a ditch does not interfere materially with the excavating action of the blast. Probably a little dirt is caught and rolled back by the side walls, but the percentage of the total lifted is small.

Waterproofing Charges

When water covers the charges you should arrange to load them and to fire them quickly. A good plan is to make all the holes for one section, then prepare the charges, as to priming and waterproofing and distributing them along the line. Quickly test each hole for fallen stones, caved-in dirt, and push the charges to the bottoms of the holes. It is best to limit their soaking to a half hour. The explosive is likely to weaken if left too long.

If the holes cave in soon after the bar is withdrawn, do not attempt to load and blast long sections at a time. In loose gravel and sand, especially where water covers the surface or nearly so, you will have trouble getting the charges down to the bottoms of holes. The best plan is to get a tin tube about 1½ inches in diameter and sink it in the hole over the bar. The explosive then can be loaded without trouble when the bar is withdrawn.

Tamping Ditch Charges

Generally speaking, a ditch charge should be tamped slightly. The more tamping you use the broader your ditch will be in proportion to its depth. If you want a narrow ditch you must let the gases rip their way upward easily. In dry or damp ground, fill the hole about half full and tamp well. When water rises high in the hole, use no tamping at all, except to tramp shut the upper 6 inches.

The ground had better be warm for ditch blasting. If it is cold you must load and fire the charges quickly, to prevent chilling of the explosive. A light crust of frozen ground makes little difference when charges are handled properly; more than 1/4 to 1/2 inch will interfere seriously.

Regulating Depth and Width

The dirt will clean out 6 to 8 inches deeper than the bottom end of the charges when conditions are normal. Explosives work more efficiently in ditch blasting when they are placed as shallow as possible. When the holes are too deep an excessive amount of explosive is required. A layer of hardpan or cemented gravel in the ground to be removed requires slightly deeper placing than soft ground. The rule for the usual job is to place the charges within 6 inches of the bottom depth desired, and for large ditches and heavy charges within 10 or 12 inches of the desired depth. The exact depth may be ascertained by trial shots.

Depth for Charges

The greatest depth it is practicable to blast at one shot is about 6 feet. If a deeper ditch is wanted, blast a second time in the bottom of the first excavation. (See table on page 98 for depths for charges.) The blasting out of very large canals should proceed along these lines. They involve no principles not explained for the making of small ditches.

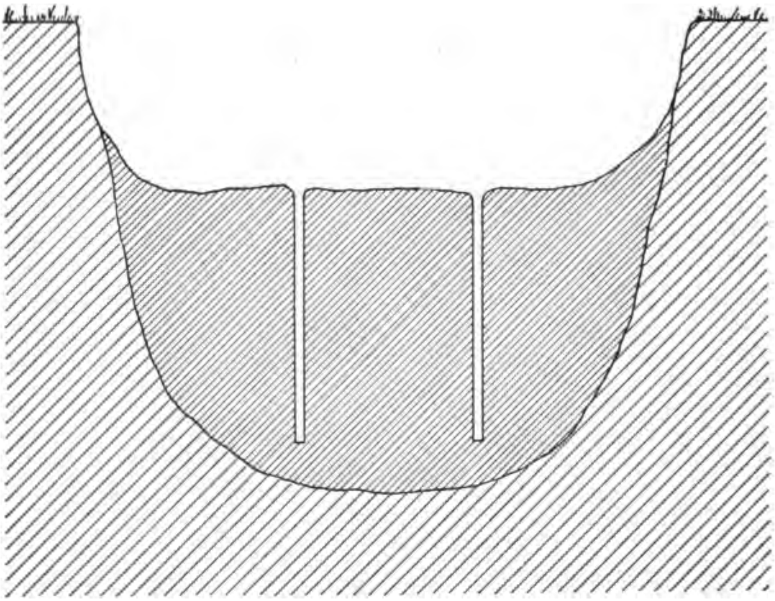
A channel 35 feet wide and 6 feet deep that was excavated by blasting. The water has smoothed the sides a little, but in the main the big ditch looks in the picture as it looked after the blast which opened it. The cost of such ditching can be figured accurately in advance when dimensions are known, the kind of soil and its condition considered, and the cost of explosions at hand. (Athens, Ga.)

One line or row of charges frequently will make a ditch up to 10 feet wide and 6 feet deep. To make wider ditches use 2 or more rows.

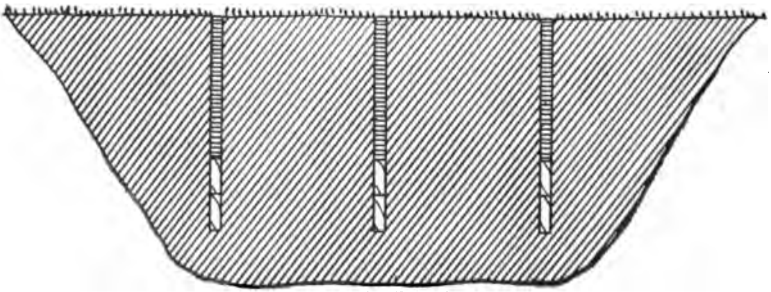
Wide Ditches

Usually 2 rows of charges will be needed for ditches between 8 and 12 feet wide if less than 4 to 6 feet deep, and 3 rows for ditches 12 to 18 feet wide.

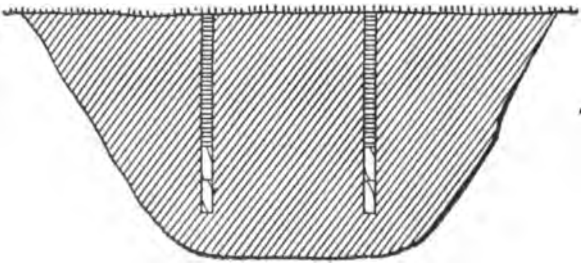
The lines or rows of charges should be placed about 4 feet apart, except where the charges consist of more than 4 cartridges and are close together in the rows on account of transmitted detonation, when the rows may be as much as 6 feet apart. In blasting out very wide and shallow ditches or canals, it sometimes is of advantage to load 2 rows with light charges rather than to attempt to blast out



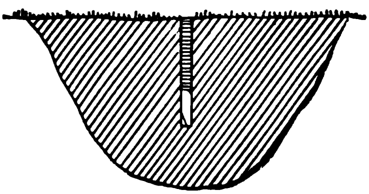
How to deepen ditch by a second blast in the bottom of a first excavation.



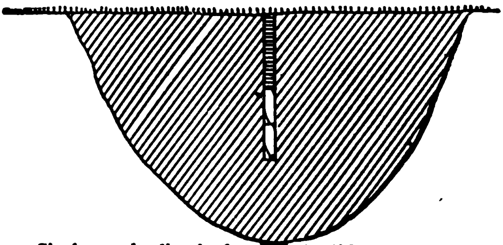
Three-row ditch loading—See page 28.



Two-row ditch blast loading.



Half cartridge loading for very small ditch.



Single-row loading for large ditch—if larger ones are needed, more rows of charges.

the ditch to the required width with one row heavily loaded. The heavy charges might dig deeper than required. (See table on page 98.)

Invariably all the rows should be fired together. This, of course, is accomplished when the electric method of firing is used. When using the transmitted detonation method, put in extra charges between the rows at the center charges, and then fire one—usually the center charge of the middle row—with a cap and fuse. All these center charges and extra charges should be *heavier than usual.* Put in an extra cartridge, at least. A still better way with transmitted detonation is to fire the center charges of all the rows together electrically.

A pond excavated entirely by blasting. Several rows of charges were loaded and fired simultaneously. The wind carried the earth to one side, forcing it to fall on adjoining ground instead of back into the hole blown out. (H. E. Ellis, Ashland, N. J.)

Amount of Explosive Required

Before giving tables of the average amount of explosive required for various sized ditches, it is well to describe a few typical examples of ditches that have been blasted, of which records were kept.

Examples

In a clay soil, with water rising almost to the surface of the ground in the holes punched for charges, charges of one cartridge of straight nitroglycerin explosive placed 18 inches apart and 30 inches deep blew out a ditch 4 feet deep, 3 feet wide at the bottom and 7 feet wide at the top.

In a similar soil, with less gravel, charges of one-half cartridge of straight nitroglycerin explosive placed 15 inches apart and 18 inches deep made a ditch 2½ feet deep and 5 feet wide. At another point in the same field, on the same day, charges of 2 cartridges (one pound of same explosive), placed 30 inches deep and 24 inches apart, made a ditch 9 feet wide and 4 feet deep.

In loam ground, too dry for successful transmitted detonation but still somewhat damp, charges of 2½ cartridges placed 2½ feet deep and 3 feet apart, and fired electrically, cut a ditch 4 feet deep, 8 feet wide at the top and 2 feet wide at the bottom.

Through a thicket with brush and small trees measuring 1 to 3 inches in diameter, in heavy pure loam well soaked with water, charges of 2 cartridges of straight nitroglycerin dynamite placed 22 inches apart and 3 to 3½ feet deep made a ditch 4 feet wide at the bottom. The ditch was loaded too heavy. Charges of 1½ cartridges would have been better.

In very wet and miry clay, a ditch 20 feet wide at the top, 12 feet wide at the bottom and 6 feet deep was blasted with 3 rows of charges of straight nitroglycerin explosive. All the charges were spaced 20 inches apart in the rows. The charges in the middle row were 1½ to 1¼ cartridges, varying a little on account of variations in the soil along the ditch. In the two outside rows the charges were one cartridge each. The rows were placed 4 feet apart. One section of the same ditch was cut out to a depth of nearly 8 feet by using 1½ cartridges to the charge in the 2 outside rows, and 3 cartridges to the charge in the middle row.

Amount Excavated By One Pound of Explosives

When the ground is fairly heavy and is full of water you can count on each pound of explosive properly placed to clean out 1½ to 2 cubic yards of earth. The variations from this rule, both ways, will be on account of the presence or absence of water, the nature of the soil and the size of the ditch. A ditch made with a single line of charges (measuring, usually, 3 to 4 feet deep by 3 feet wide at bottom and 6 to 7 feet wide at top), will give the highest efficiency, and when the conditions are very favorable will show even a little more than 2 cubic yards per pound of explosive used.

As the amount of excavation in one body increases, the efficiency of each pound of explosive will fall off somewhat. In very large ditches that are wet you will get out only 1½ cubic yards per pound of powder. In dry ground blasting, particularly if the ground is light, 1¼ or even one cubic yard per pound will be the average.

Number of Half-Pound Cartridges of Explosive Required per Charge for Blasting Ditches

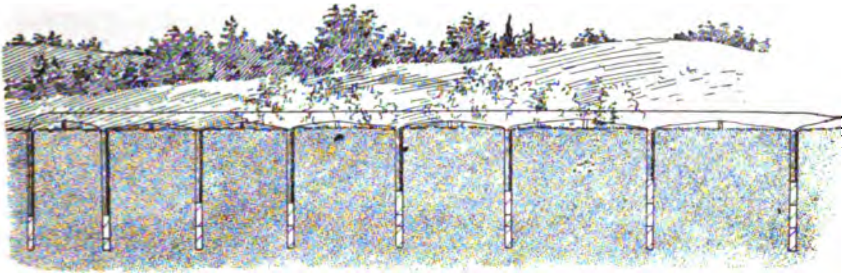
Depth Ditch	Depth Hole	Amount Charge Transmitted Detonation	Amount Charge Electric Firing
2 ft.	1½ ft.	½ cartridge	½ cartridge
2½ ft.	2 ft.	¾ cartridge	1 cartridge
3 ft.	2½ ft.	1 cartridge	1¼ cartridges
4 ft.	3¼ ft.	1½ cartridges	2½ cartridges
5 ft.	4¼ ft.	2 cartridges	3½ cartridges
6 ft.	5 ft.	2½ cartridges	5 cartridges

The width of the ditch can be calculated by doubling the figure for the depth in case of a single row of charges, or in the case of more than one row, by adding to the figure for double the depth the distance between the rows of charges.

The table given above is correct for average conditions. Since variations in soils, temperature and other factors make necessary varying loading, the figures here should be used as a guide for starting test shots.

Making Test Loadings

No ditches should be blasted without testing the loading thoroughly before proceeding with much work. Blast small sections at a time, and vary the loading to suit the changes in the nature and condition of the ground you encounter along the ditch line. Clay, sand, muck, loam and gravel all require variations in depth of charge, amount of explosive and sometimes in spacing of charges. Proper tests will enable you to decrease the cost and to make a better ditch than otherwise would be possible.



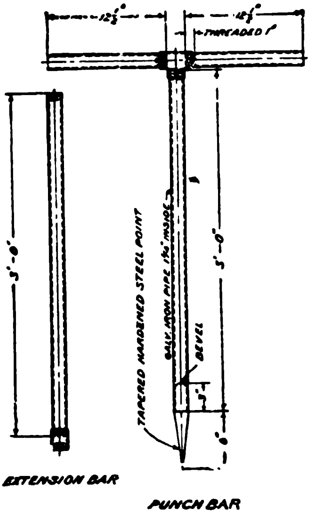
Typical test loading to determine proper charges and placing of explosives for electrical firing. Note the variations in spacing between holes as well as in amount of explosives used. (See page 90.)

Five to ten holes make a good test. This should be repeated several times. Vary the depth and spacing and the amount of charges. *Remember that proper blasting will make perfect ditches at low cost, and that the only final way of determining proper loading is to try it.* Well-balanced charges will be so loaded and spaced that the gases will lift the full load of dirt without overlapping much and without skipping any ground between. Load just heavy enough to insure clean excavation without excessively high throwing of dirt.

Time Required

Making 3-foot holes in clay and gravel, preparing charges, loading and firing can be done by one man at the rate of 20 to 50 charges per hour. If there are many stones in the ground, or if the ground is hard, the work will go more slowly. Wet gravel makes slow work. Two or more men will get more done in proportion than one man. Under favorable conditions one man has blasted out 1,000 feet of ditch 3 feet deep in 12 hours. One man should be able to blast 350 to 450 feet of ditch per day through brushy ground; if the land is clean he can do more, though where ground is so dry as to cause trouble in making holes, the work will go slowly.

A crew of ten men—eight laborers, one blaster and a boss—working at a big ditch. The employment of so many men is not justified except for very long ditches, for the job lasts only a day or two. A good sized crew enables the blaster to place and to fire the charges quickly, which is an advantage when the holes fill with water and when the temperature is low. (Max Ostner, Diehlstadt, Mo.)



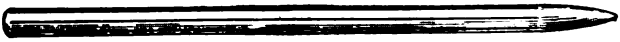
How to use pipe to make a punch har or to extend an auger.

Tools Required

Ditch blasters should have a soil auger, two crowbars, a sledge, a couple of long-handled shovels and a cutting spade. One of the bars should be 4 or 5 feet long and should be constructed for driving. The other should be 6 or 7 feet long, and may be made of piping, with a solid sharp steel point welded in. It is for use as a churn drill, without sledging. A broomstick or a wooden rod about 1½ inches in diameter, for pushing the charges down and tamping, and an axe to help cut roots, also are handy. Of course, boxes or baskets for carrying explosives, cap crimpers and the usual outfit for handling and loading explosives as described on pages 36 and 37, will be required.

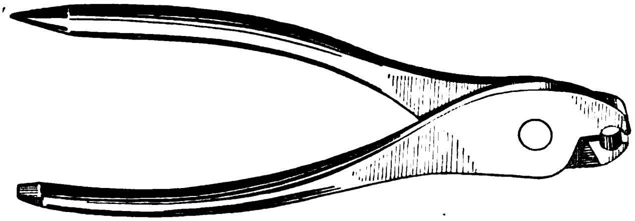
Incidentals

Large stumps, stones or other obstructions along in the line of the ditch require a little extra explosive. Stumps up to 6 inches through and boulders up to 18 inches in diameter will be thrown out by the regular ditch charges. Above these sizes use extra loading, as follows: For each 6 inches of the diameter, use one cartridge of explosive. For stumps larger than 30 inches, use 3 to 4 cartridges for each foot of diameter. Put the extra explosive directly under the stump or stone.

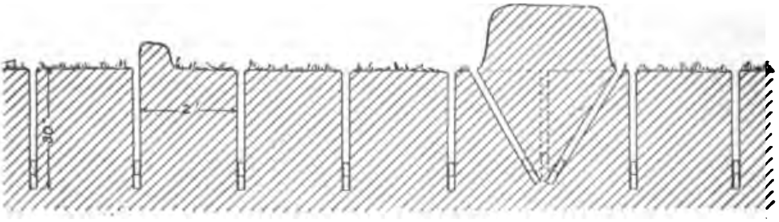


Steel bar for making holes.

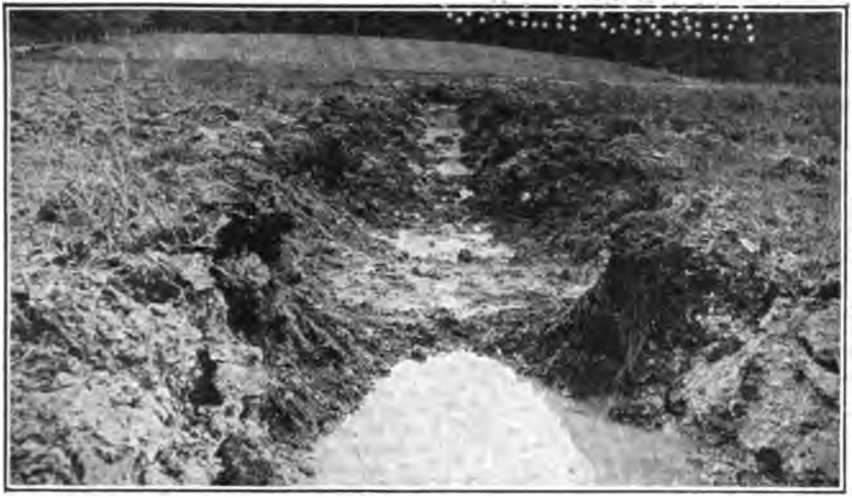
Soil auger—note long point.



A good kind of crimper.



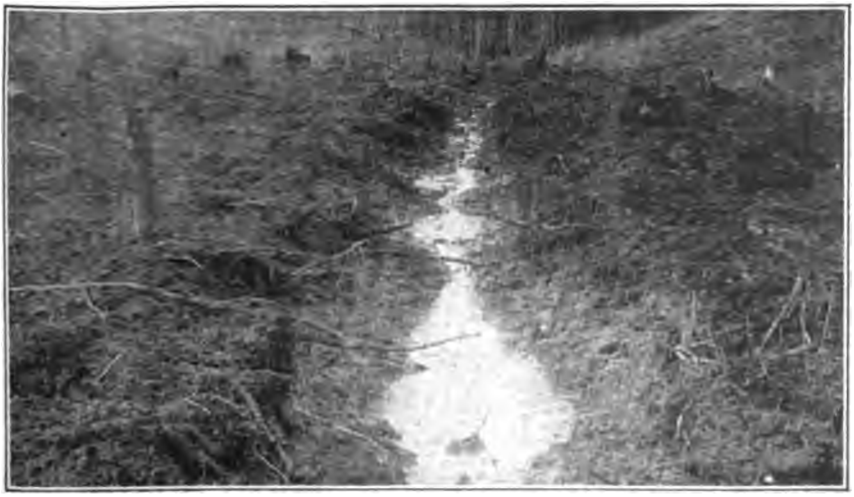
How to place charges under obstructions in the ditch line.



Through heavy sod, as shown here, blasting cuts the sides somewhat irregularly unless the grass roots are first sliced with a shovel blade or hay-knife. This ditch is well opened and entirely successful, but a good many projecting chunks of sod are left sticking from the sides.

Finishing Ditch

Ditches blasted through ground that has a raw surface and no roots will require no finishing afterwards. The edges and sides should be fairly true and even and the dirt should be well scattered. There will be few or no ridges along the ditch. Even through sodded ground and through woods and brush, when the sides of the ditch have been cut before blasting, there will be little hand work needed. If no preparatory cutting is done, however, some shoveling to smooth the sides and some cutting to take out projecting roots and sod may be advisable.



This ditch was blasted out on a still day, and most of the dirt fell straight back to the ground. But it was spread out so that only a little of it fell in the ditch. The few roots projecting into the excavation can be cut off with little trouble. It is the roots of sod and matted roots of smaller brush and trees which give the trouble in blasting and require cutting beforehand. (Robert Jemison, Birmingham, Ala.)

This work should be done right after the blast, before the water has a chance to compact the sides. If necessary, leave dams of unblasted sections 3 or 4 feet long every few hundred feet in the ditch, to hold back the water long enough for finishing. They can be blasted out afterwards. An old axe or a sharp grubbing hoe or adz will cut the ends of roots easily. But all this work can be avoided and a better ditch result if you will do the cutting before the blasting. Large clods, pieces of stumps or roots and stones in the ditch channel after blasting should be thrown out without delay.

It has been stated (page 79) that ditches for tile or pipe cannot be blasted out satisfactorily. The dirt can be loosened with light charges, however, and the shoveling or excavating by other means thereby made much easier. If the pipe is to be placed deeper than 4 feet, it is even practicable to blast a 3-foot or deeper ditch on top, leaving only a little more excavating to do in the bottom. One must bear in mind, however, that the blasting throws dirt too far away to be shoveled into cover piping. Loosening as explained above, however, to make digging easier, does not throw the dirt away.

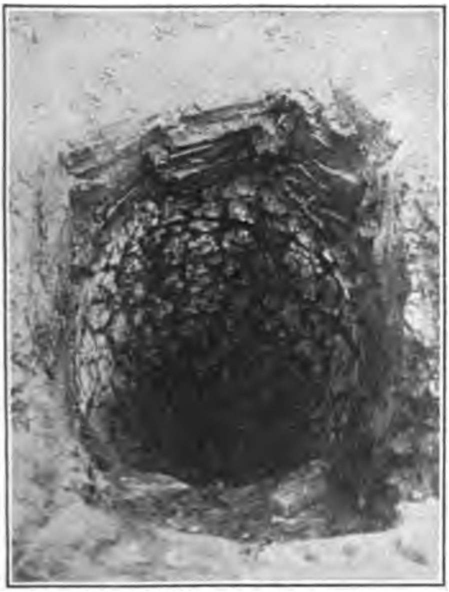
Two post electric blasting machine—
push down type.

Blasting Orchard Soil

The blasting of soil for tillage purposes was first tried more than a generation ago. Since 1900 the practice has become general in many sections of the country, particularly in those localities where orcharding is one of the main businesses.

The experiences of individuals and of official investigators have not been uniformly successful, though some remarkable results have been secured. When the idea of blasting soil for tillage first was freely offered to the public through advertising and the editorial matter of farm papers, many unjustified and foolish claims were made for it, and a great many mistakes were made in the actual blasting. These claims and mistakes are to be regretted, because they led to barren or damaging results and to uncalled-for criticism of proper blasting.

As a general statement of the proposition, it may be said that soil blasting is to be regarded largely as intensive tillage. Its benefits are derived from its physical breaking and mixing, opening and loosening of the soil, and show themselves in the form of better drainage, an increased supply of moisture in dry weather and better root penetration, and because of these, in the greater fertility of the soil.



This is the kind of result produced by blasting ground when it is wet, and sometimes by using too-quick acting an explosive in moist ground. The soil may be left in a worse condition than before the blast. See page 131.

The movement to blast soil was at first popularly called "deep plowing" or "plowing with dynamite," but most farmers have come to know that blasting soil is in no sense plowing it. Blasting will not replace ordinary plowing, nor can plowing be made to do the work of blasting.

The whole matter of orchard tillage and feeding must be taken up when soil blasting for the benefit of trees is to be considered intelligently. Blasting is but one spoke in the wheel. Much of the misconception which exists to-day regarding the value and benefit of blasting orchard soil is due to failure in grasping this fact.

The subject necessarily is a technical one, and this bulletin must deal with chemical and mechanical processes of the soil, using technical language to some extent. But as far as possible the matter is kept to broad general principles known and accepted by the great majority of agriculturists. The problem is to find out whether or not the kind of tillage which blasting gives will produce beneficial results, and produce them at a cost within the reach of commercial orcharding.

This hole was blasted out when the ground was much drier than at the time the crater in the other picture was blown open. Instead of the sides of the crater packing, they loosened and crumbled. But even this ground is not as dry as it ought to be. Also a subsoil blast never should blow out a "hole." See page 131.

What An Orchard Soil Must Do

When attempting to form judgment of soil tillage by blasting or to explain it, we should have clearly before us what we want to do with the soil and what we expect the soil to do for trees.

The purpose or idea of cultivation of orchards is to get profitable growth and yield from the trees. That is obvious. We want the greatest net profits possible under the conditions of each orchard. No one pursues a system of cultivation for the sake of the system itself, although the farmer or fruit grower does a great deal of tillage work rather blindly and without knowing just why he does it or understanding the soil processes he is dealing with.

But it is clear that to make trees grow and yield to their maximum capacity, requires so far as the soil is concerned, *enough water, sufficient of the right plant foods, and root anchorage and feeding space.* These 3 essentials for growth are delivered to trees only by the soil, and the work of the soil consists in supplying them to the trees. It must be in condition to deliver them.

The Soil Problems in Orchards

Correct fundamental education in the principles of soil nature and management is so universal nowadays that the primary facts regarding the growth of plants, and their feeding habits, need not be discussed in detail in this bulletin. It is enough for the purpose to say that every reader is presumed to accept the facts that the plant foods which have to be supplied are nitrogen, potash, phosphorus and lime. These are the only ones out of the 20 or more elements used by plants as food which run short in the soil, largely because they constitute the great bulk of the materials, aside from water, that are taken up by trees. The source of supply of these important elements are, on the one hand,

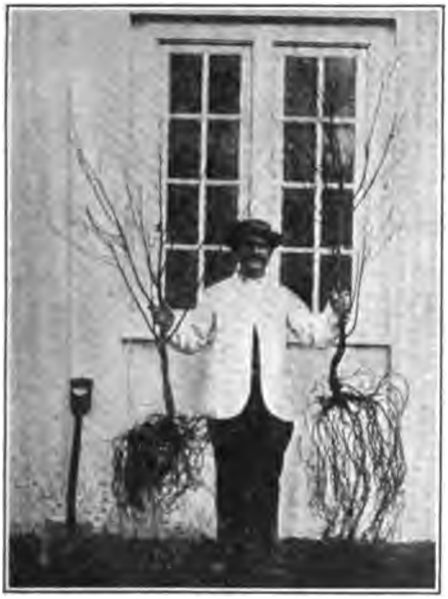
The Plant Foods

artificial fertilizers and manure, and on the other hand, the soil itself (though nitrogen is derived from the air by means of soil processes).

Drainage and Moisture Storage

The water problem is not less well defined and understood. To some extent it consists in draining away surplus water from wet places and swamps, and in making certain of the effective drainage of all land during winter, spring and rainy periods of summer. To a greater extent it is a matter of storing enough water for the use of the trees during the growing season. No orchardist questions the fact that the lack of moisture very often is the limiting factor in growth and crop production. The moisture problem perhaps is the most serious one which fruit growers have to face.

Root anchorage and feeding space (considered as one factor) give relatively less trouble than either a correct water supply or a proper supply of plant food. The latter factors must receive attention in all soils; the former only in certain soils of a hard or uninviting nature, or which are in bad condition owing to improper treatment. A light, porous, fertile soil offers no difficulties to roots in their penetration and food gathering, but a hardpan soil, a heavy clay or a cemented gravel soil does offer serious difficulties.



These two trees were washed out of the ground with a stream of water from a hose, in the fall of their first season after planting. The one on the left had been set in an ordinary hole, dug as usual. The one on the right had been set in blasted ground. The soil is typical redshale (Upshur), classed as clay loam. (New Jersey Experiment Station, New Brunswick, N. J.)

Root Anchorage and Spread

All orchardists agree that an extension of the root anchorage and feeding scope of trees is beneficial and desirable. Authorities continually remind us that we should drive the roots down away from the surface. One of the tests of the thrift of a tree is to examine its roots for the size and nature of their growth. If they are long, ropelike and few, the tree is starving. If they show as a mass of fibers growing from well proportioned main branches, which extend to a fair distance in every direction, the soil is full of the needed foods and moisture. Only trees which are firmly and deeply rooted will stand up against windstorms and under loads of fruit. It is largely to bring about the conditions outlined that orchard ground is cultivated.

What Soil Is

The material we call soil may be described as the outer layer of the earth. The soil includes loam, clay, sand, gravel, boulders and even ledges of rock. To limit the soil to the earth penetrated by roots would leave out other material underneath of exactly the same stuff. To limit it to what we call loose earth, leaving out rock, shale and the like, would not be correct, since the rock and the soil are composed of the same elements. Often the point where "soil" begins and "rock" ceases is indistinct, as in the case of hardpan, for instance.

Origin of Soil

The loose earth, or ground, is only particles of rock that have been more or less changed by and mixed with the remains of plants. There was a time when there was no loose soil. The surface was rock. As the seasons passed, water dissolved and wore away particles of the rock. After a time mosses and rock plants appeared and sent their roots into crevices. The roots grew and helped to split off other fragments, and when the plants died their material gave off acids which helped the water to dissolve more rock and to dissolve it faster.

Frost and heat from the sun hastened the processes till the softer minerals separated from the harder ones, and what was not washed away by running water caved in and became mixed with dead moss and the decaying roots and stalks of grass and other plants.

This is soil at the present time, whether it is hard or soft.

Top-soil and Subsoil

The top-soil of cultivated land ordinarily shows a much more advanced stage of this breaking down process than the subsoil. The top-soil, which usually is the layer reaching to the furrow depth, generally is darker colored, from the greater amount of remains of plants it contains. It differs from subsoil in porosity, moisture content, bacterial activity and in other ways which will be explained fully farther along in this bulletin.

Whatever the difference, *it is largely a difference in the stages of decomposition or disintegration of the mineral particles,* and of the amounts of organic matter present. Both surface and lower soils are essentially of the same chemical make-up and they both may have come from identically the same kind of rock. The ground near the surface has been exposed to action of heat and cold and water and air and plants, and has been changed more than the ground under the surface. The more the soil is broken down from the original rock the finer the particles are, and in general, the more fertile it is.

The "Strength" in Soil

It is well at this point to call attention to the latent strength in the soil, to counteract any tendency toward the belief that you must put back in as much as you take out. The soil is not a sort of empty mill into which you pour plant food and take out crops. It is to a large degree an inexhaustible mine of many plant foods. As evidence, look at the immense growth that has arisen from it in moss, weeds and forests during the thousands of years past. If all this growth were piled up it likely would weigh as much as the soil itself to a great depth. In the soil and air now, waiting to be released and used, is substance enough to create food for all the people of the earth for years without end. In the soil of your own orchard and farm you likely have nearly all the plant food elements your crops ever will need. Make them available for roots, add to the supply the few that are short, and in crops you can profit from nature's riches as surely as though you were digging gold or coal.

The Relation of Tillage Blasting to Soil

That "tillage is manure" is no new thought. The phrase itself originated a great many years ago. The proof of its truth lies in the very nature of soil itself, which has been explained in the preceding chapter. Tillage, which is the stirring and mixing of soil, promotes and helps these natural processes which first changed the rock into soil, and which now tend to make the soil fertile.

Tillage Produces Fertility

A good, deep plowing, followed by thorough harrowing, opens up the soil so that roots can penetrate it easily. It introduces air. It helps to maintain moisture in dry weather. It exposes a new part of the soil to frost and to sun. A new supply of the plant food elements which the soil contains is liberated, or it is better to say their liberation is hastened, and trees are given a better chance to grow.

The so-called "run-down" or "worn-out" soils contain almost as much of most plant food elements as ever. But instead of the soil being soft and mellow, it has reverted and become harsh. A run-down soil shows under chemical analysis a composition not greatly different from what it does before becoming exhausted or after it is made fertile again. The only vital difference is the *state or condition* of the plant food elements.

Tillage alone of course will not keep land from running down. Plants also are needed for supplying vegetable matter in the soil. Their dead roots and stalks hold the particles of the soil in crumbs, increase its moisture holding capacity and help to maintain conditions under which further decomposition occurs continually. Without tillage the plants will not grow or at least will not become mixed with soil farther down than a few inches.

Cherry trees three years old, with corn intercrop, which certainly takes some plant food. The soil naturally is no better than in the other part of the same orchard, shown on opposite page, but it was well broken up with explosives.

Under wild or forest conditions with no tillage, the fertility of the soil is maintained and even increased, but the processes are very slow and the result is long in coming. In orchard soil the processes must be hastened so that the natural forest changes of 25 years take place in one.

When an explosion takes place in soil, the gases escape in all directions from the place where the dynamite charge was located. Those gases which start downward and sideways soon curve upwards. They travel sideways several feet through the soil. They lift the soil in mass and make it break and crumble, and can be detected rising from the ground over a circle 10 to 15 feet in diameter about the position of the charge.

The gases of an explosive will rebound from a substance that is extremely hard or resistant, but they try hard to travel in a straight line in the original direction. When confined in hard soil, they strike against the resistance, and because the mass of soil is not firm enough to turn them aside, it is broken and crumbled. They smash right through compacted sections. This fining and crumbling action can be compared to the effect of pounding up a brick with a hammer. The tens of thousands of particles that had been clinging together in one hard mass are separated.

It is this fining and loosening which makes so valuable the particular kind of tillage which blasting gives. (It is intensive tillage—the kind which is "manure.") In modern agricultural practice intensive tillage is recognized as one of the best means of securing large crops—in fact, it is recognized as a necessity in orchards and in fields and gardens where intensive crops are grown. Blasting is tillage of the most intensive kind it is possible to secure by any practicable means.

The limit of plowing, even with deep tillage implements and subsoilers, is 16 to 18 inches. The shallowest blasting should reach to a depth of 36 inches,

In this orchard the trees are *seven* years old, but much smaller than the other, three-year trees. The fine growth of clover proves that top soil is fertile and in good condition, yet it does not grow trees as well as the blasted soil.

and the average work is done so as to reach to 48 inches or deeper. The real significance of such deep, intensive tillage is so far beyond the mere superficial appearance that it must be explained in separate chapters.

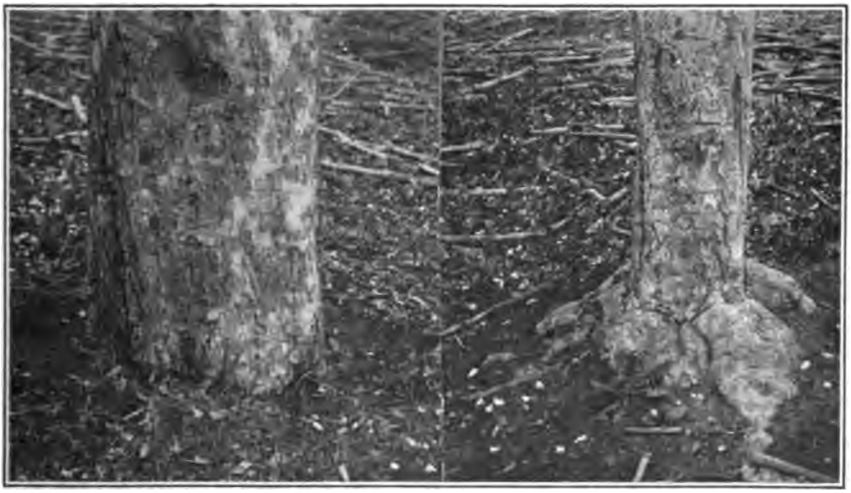
How Root Growth is Helped by Deep Tillage

A mature apple tree should have a root system spreading twice as wide as its spread of limbs, with some roots at least 10 feet deep, and a large part of the root system deeper than 2 feet. With roots less well developed and distributed, the tree is bound to suffer from lack of water, and plant food, and possibly from wind.

Depth and Length to Which Roots Grow

Fully developed peach trees have root systems smaller in proportion than apple trees. Pear, plum, quince, cherry, nut trees, citrus fruits, and the semi-tap root shade trees in mellow soil develop root systems not greatly different from apple trees in extent. Some ornamental trees, such as Norway pine and shagbark hickory, often grow half as deep into the ground as the trunk is tall. Grape vines have roots extending in every direction to a length out of all proportion to the size of the vines above ground.

These developments occur only when the ground is as loose, fertile and well watered as it should be. In orchards or hardpan soils and neglected soils, the roots grow out to a length less than the length of the limbs. They go down until they strike a compact layer of clay, a layer of hardpan, or the water table. Unless forced and coaxed down by cultivation, they grow up until you can see them where they bend above the surface.



The apple trees in these pictures were planted 19 years ago, in soil with hardpan about a foot under the surface. The tree at the right, in the picture, was planted without breaking up the bed with explosive; that at the left set in blasted ground.

Today some of the trees not growing in blasted ground are dead, while all those in blasted ground are living. Those in blasted ground average 25 feet high, and in unblasted ground 18 feet. The former trees have an average spread of limbs of 25 feet; the latter, 16 feet; while the trunks of the two sets of trees measures 3 feet 7 inches and 2 feet 3 inches, respectively. In the blasted ground the trees stand "shoulder deep," and over the unbroken hardpan the roots are raised above the surface, as the pictures show.

This is one of the most striking instances of the damaging effects of a hard and impervious soil that has ever been examined carefully and photographed. (Geo. W. Brown, Mount Cory, Ohio.)

The big root systems can be picked out by the appearance of the trunks and tops of the trees. No small, scrawny trees have well-developed and widely extending roots, nor will any large, thrifty trees have short and meagre roots. A tree that regularly grows and ripens a heavy crop of good sized fruit must have a big, deep root system. Any tree that does not cannot do the work. It follows, in view of these facts, that every orchard and ornamental tree should have roots extending as wide and as deep as possible. One or 2 feet deep is not enough. With roots only at such depths the trees exhaust the little bit of moisture within their reach during 3 or 4 weeks of rainless weather; or worse, they may be blown over by the first stiff wind.

Young trees have even greater need of proportionately big root systems than mature trees. Their roots need to go down 3 feet at least by the end of the second year after their planting and should extend laterally 6 to 8 feet then, even if the trunk is only 4 feet high. All that is said about root growth applies equally in the case of the newly planted tree and the tree that has been in place many years.

The Causes of Restricted Root Growth

The limiting factor as to depth of root growth may be some form of hardpan or cemented gravel, compact clay or other soil, poor drainage, or simply that the soil contains neither enough water nor enough available plant food.

Hard Soils Difficult to Penetrate

An idea of the difficulty encountered by roots in penetrating soil can be had by noting the method of their growth. A hair-like or pin point of a rootlet presents its tip in the direction it is growing. This new tip then expands like a bud in the spring, pushing back and lifting the soil or earth out of its way.

When the soil is soft and porous, the roots find little difficulty in penetrating it, because its minute air spaces serve as ready-made tunnels; but when the soil is compacted or cemented, as it is in hardpan, in hard gravel deposits, and in all harsh soils having little organic matter, the delicate, minute roots are compelled to do work which almost would defy a steel rod.

True hardpan is semi-rock. You cannot crumble off the edges of a chunk with your fingers. The softer type can be cut with a sharp knife, as clay can be cut, but the point of the knife cannot be forced into it without pressure or pounding. It is not surprising that such soil resists root penetration.

Hardpan is Like Wood

A hardpan layer, or one of clay, plowsole or other structure, can be compared to a plank floor underground. The roots will run along it in the softer soil, but they will not penetrate it. When a young tree is planted in a small hole dug in compact soil, it is, practically, in a wooden tub. The roots have to force their way through the hard sides in order to develop as the roots of a tree should.

The compact layer of soil may occur within 6 or 8 inches of the surface of the soil, or may be down a foot or 2 feet or more. Where within 2 feet of the surface, it often forces the roots to lift the crown of the tree entirely above the surface. If the entire root anchorage and feeding space of a tree is confined to the first foot or two of soil, it cannot grow or yield to anything like its maximum capacity.

To help to make clear the great difference in the case of root penetration

Porosity of Soils

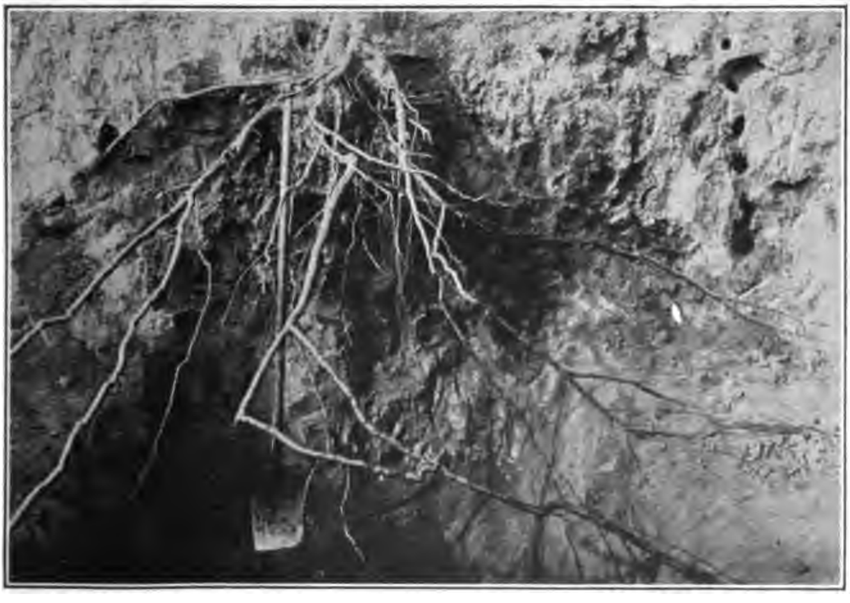
through hardpan, stiff clay or other tight soil, as against field soils in mellow condition, a statement of the amount of air space in soils may be of value. When a hardpan, clay or gravel soil has been thoroughly compacted by water or other agency so that the particles are packed as close as possible, *the air space (or pore space or porosity) is only 5% to 10%.*

The soil is 90% to 95% solid. This is the hardpan, cemented gravel and plowsole condition. But the average air space in soils in good condition is 6 to 13 times as much, as the following table shows:

Approximate Amount of Air Space or Pore Space in Soils in Good Tilth

Clean sand	33 Per Cent.
Coarse sand	40 " "
Medium sand	41 " "
Fine sand	44 " "
Sandy loam	51 " "
Fine sandy loam	50 " "
Silt loam	53 " "
Clay loam	54 " "
Clay	56 " "

The nature or character of the root growth is modified by the comparative mellowness of the soil. The ideal feeding roots, it is everywhere agreed, are fine, fibrous and not long. The main or anchorage roots should extend well



The nature of root growth of fruit trees depends on the condition of the soil in which they grow. The ground was dug away from the roots of two trees, leaving the main roots in their original positions—(See next page) out from the tree and down deep, gradually tapering from a thick base to a slim point. All along them the tendril-like feeders should grow out like the legs of the so-called "thousand-legged" insects.

In a tight soil the main roots usually grow short and stubby, with few of the fine feeding roots. In a very poor soil the main roots lengthen into veritable ropes, traveling on and on in search of food. They are usually almost bare of feeders. Under any conditions of soil except that of the best tilth an excessive part of the strength of the tree has to go into root building and root penetration, rather than into food gathering. Too much time is consumed in growing the root. Five years may fail to develop a root system equal in food gathering capacity to a system developed in one year in soil of proper texture.

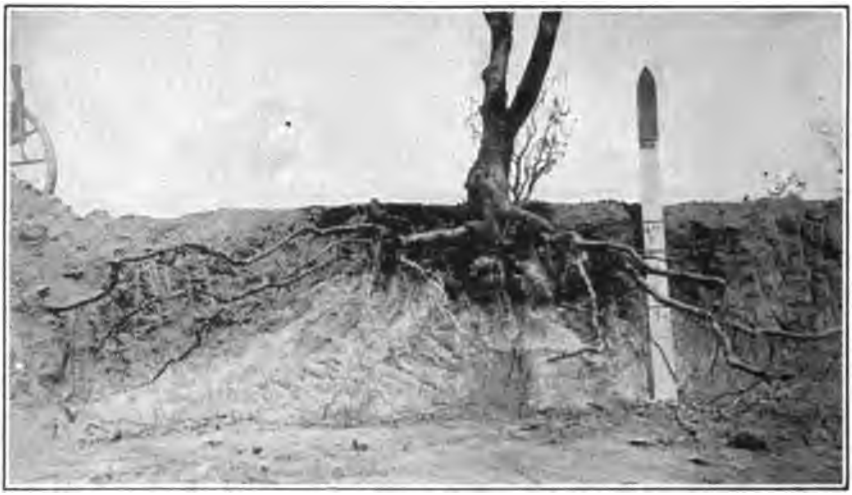
The limited digging usually done in making holes for planting trees serves to give the roots a brief start. The hole should be dug at least 3 feet deep and 4 feet square, but few indeed are the instances of the digging of such large holes in commercial orchard planting. The usual practice is to scoop out just enough ground to let in the severely trimmed roots to the required depth.

Tree Holes Dug by Hand

Quite often young orchard and shade trees are set in holes not more than a foot deep and 18 inches wide. The sides of the holes frequently curl the ends of the roots back like clinched nails. An examination of trees that have been dug up or washed out a couple of years after they had been planted in dug holes, shows that masses of matted and twisted roots have been confined in the hole that was dug, almost like the roots of a large plant in a small flower pot.

How to Secure Big Root Development

The way to do this is to break up the soil with tillage, and to make it fine and porous. Tillage with plows and cultivators can be extended to a depth



—Note how the hard ground under the one tree kept practically all its roots in the top two feet of soil. The soil under the other tree was lighter and more porous, but not fertile, consequently the roots grew like long ropes, traveling many feet in all directions. Both are poor root systems.

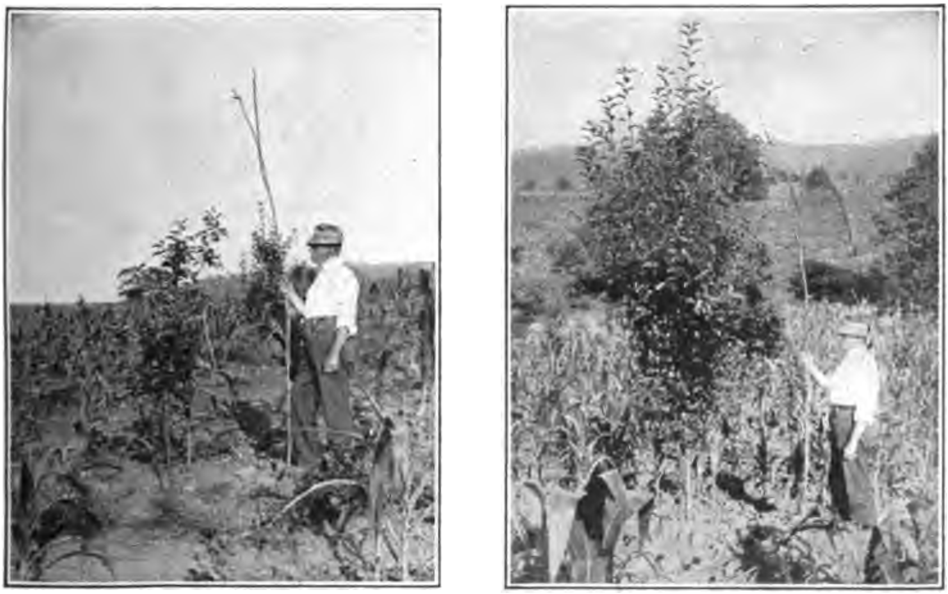
Deep Tillage Insures Big Root Systems

of 8 inches without trouble. By using subsoil attachments and deep tillage disk implements 18-inch tillage is practicable. Where it is desired to go deeper, hand digging and blasting are the only means available. Hand digging of all the soil is impracticable in commercial orchards, but if the cost does not matter, the ground of home fruit gardens and lawns can be worked over by hand to a depth of 4 to 5 feet by digging wide trenches and shoveling the ground back from each new trench into the old one. This is a common practice in many European gardens.

Tillage by blasting is pre-eminently the most advantageous treatment for the soil that is hard enough to restrict root growth or to hold free water. In a previous chapter the action of a proper blast has been described. It is clear that the explosion, in breaking up the hardpan or the plowsole or the layer of stiff clay or cemented gravel; in opening cracks through the soil in every direction, and in crumbling and fining the earth to a depth of 4 or 5 feet or more, as you place the charge, supplies just the treatment needed. By no other practicable means can the soil be worked to an equal depth, and in no other way can even the top 2 or 3 feet of soil be worked so thoroughly at a reasonable cost.

Roots in Blasted Ground

After considering the foregoing facts the thinking man will need no concrete examples of better root expansion in well tilled soil to convince him that roots will develop when given the chance and the incentive. The illustration on page 105 shows this so well that every reader should look at it now. Two young trees were washed out of their beds. Both had grown one season. The root system of the one in blasted ground is about 4 times the size of the other, and it is of a better character.



In the orchard where these two trees are growing are many thousand set in blasted ground and a few hundred in unblasted soil. Not as many died as a result of planting each 1000 in the deeply loosened ground as of each 100 in the unbroken soil. The growth made by each class of trees up to the end of the second year after planting is shown in the pictures, which are of typical trees from each lot. (The Belmont Orchard Company, Charlotteville, Va.)

Amount of Increased Growth

This example is not advanced as typical of all results. The growth that will be made by any tree cannot be predicted. Too many other factors aside from the condition of the soil enter into the matter. The fact that some trees in properly blasted ground have grown as much in 2 years as others in unblasted ground have grown in 4 years is no guarantee that all trees will do as well, or may not do better. If the blasting is not done right no benefit at all may be derived; indeed, there are cases on record where positive damage has been done to soil and to trees by improper blasting.

Soils That Should Not be Tilled Deeply

There are but few soils in which intensive tillage of any sort will not help the root growth of trees. Among them may be mentioned loose, light sand, gravels and loams which are as porous and mellow as they should be without further loosening. The volcanic ash soils of some Rocky Mountain states need no deep tillage unless underlaid with more or less crusted lava.

Whether or not to blast loam soils to secure better root penetration depends on their character and condition. If they are deep, well drained and well supplied with humus, the chances are that little increase in root growth will be derived from any sort of deep tillage. But considerations in respect to moisture storage and the liberation of insoluble plant food nearly always call for tillage and yet more tillage. Roots of cover crops must penetrate the ground in order to keep soil fertile. Hence few soils aside from those named above will not be benefited by deep tillage.

Correct methods of doing the blasting to put soil into proper condition for root development and for other purposes are described on pages 131 to 138. On page 140 you will find a discussion of the length of time one thorough breaking up of the soil may be expected to last, and of how the needs of trees may be met both at the time of planting and years later, when the roots have extended themselves many feet in all directions.

How Soil Water is Governed by Deep Tillage

In every orchard soil the water problem is two-fold. Surplus water must be drained away and sufficient moisture for use of the trees during dry weather must be stored. Both purposes are served by tillage in ways that are made plain in the following explanations.

Leaching

The drainage must be effective enough to take away the excess water quickly, but the flow of water must not be so fast as to leach or float away much plant food. Whenever the excess water is permitted to run over or through the soil in trickles, it leaches out available plant food. It should filter away—without delay or damming back, but still filter—through beds of fine, granular soil.

The water should escape at a lower level into a ditch or into a loose layer of gravel or sand that will carry it away. In orchards the level of standing water in the soil must be well below the depth of root penetration if the trees are to grow and yield well.

Conditions Necessary for Drainage

To a great extent the drainage problem is to put the soil in condition by tillage to act as a filter bed. The soil must be kept loose enough to let the water seep and percolate through. Layers of tight soil, such as compact clay

Proper Drainage

or hardpan, hold the water as though it were in a tank or a pan. It cannot escape except by evaporation. Such tight soil must be broken up to a depth that will permit the lowering of the water-table below proper depth for root growth.

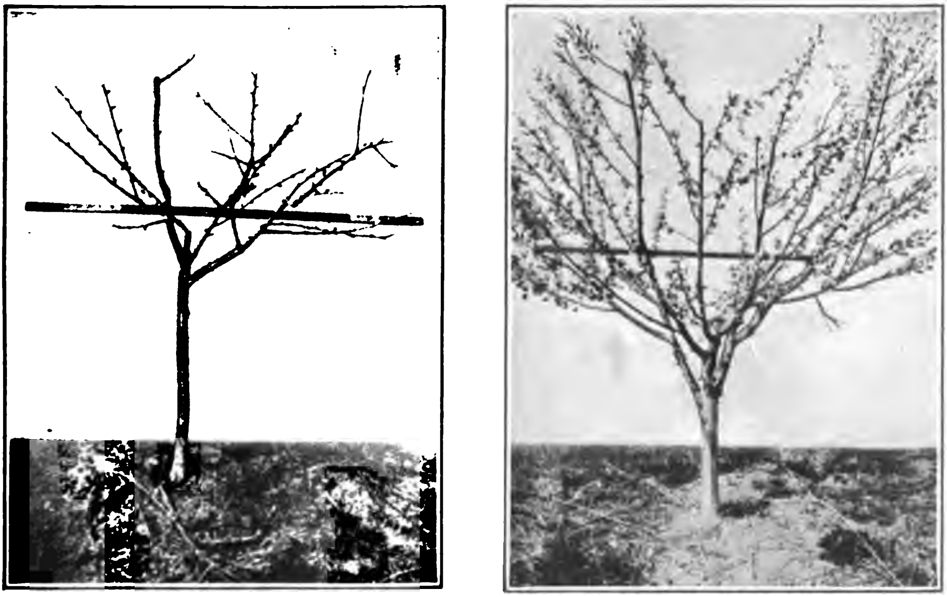
If the layer is thin—say only a couple of feet through—all of it can be reduced to fine particles. When it is thicker than 4 or 5 feet it cannot be broken entirely through to softer ground below except at prohibitive cost, and the effort should be to create a zone of proper condition in the top 4 or 5 feet of the ground. From this the water should drain away into ditches.

Even in soil containing no clearly defined hardpan, the general texture and condition may be such as to make drainage poor. Tillage will remedy this condition, by opening up and fining the soil so that water can move about in it freely.

The statement of the porosity or air space of soils in the chapter on root penetration (page 112) will be interesting in this connection. In a hardpan or thoroughly compacted clay there is an average pore space of only 5% to 10%, but when the same soils have been reduced by thorough tillage to a proper condition of tilth they contain upwards of 40% on the average, or 6 to 13 times as much pore space. In other words, nearly half of the bulk of the soil is air space, open to the free movement of water. Naturally such well-tilled soils are well drained.

Moisture Storage

The amount of water that in a dry season must be stored somewhere in the soil, available for the trees, can be stated with a fair degree of accuracy



A direct comparison in growth. The superior soil conditions brought about by intensive deep tillage are responsible for the gain of the one tree over the other. Such marked results are not always produced by blasting, however—only when the soil is of a nature and in a condition to respond quickly and heavily to the action of air, moisture and bacteria. (Auburn, Ala.)

Amount of Water Used by Plants

in terms of inches in depth. It must be based, of course, on the needs of the crop of twig growth, leaves and fruit. For each ton of material grown (dry) it is safe to say that at least 3 inches of water will be used by the trees. If the orchard crop weighs 5 tons to the acre, which probably is less than the average, the amount of water required is 15 inches in depth over the acre. This amount meets only the actual needs of the trees, and does not allow for much waste through surface evaporation.

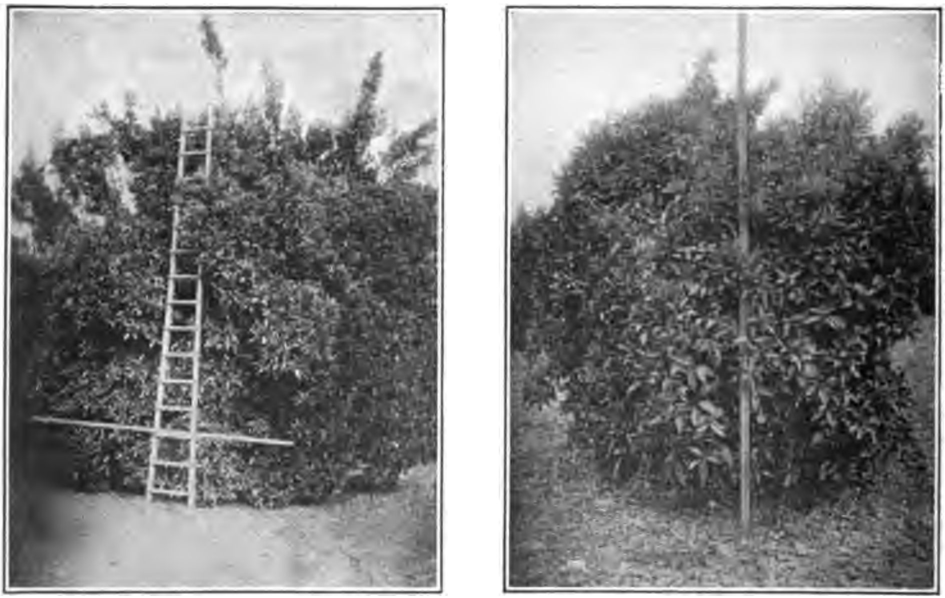
Fifteen inches of water is the net amount that will be required to make the growth and yield of the trees. Less water available for the roots will mean decreased growth and fruit production. If irrigation is not practiced, the one safe procedure is to store the required amount of water in the ground, for rainfall is uncertain, and cannot be depended on.

Amount of Water Stored by Soils

The capacity of a well-drained soil to hold water in a condition in which it is useful to trees depends on its structure and condition. Laboratory tests of average field soil in excellent tilth have shown in the first 4 feet down from the surface the amounts of water given in the table below.

Amount of Water Contained and Useful in Different Soils When Tilth is Good—Top 4 Feet Fully Loaded

	Amount water (inches deep)	Water weight	Unavailable	Inches available
Coarse sand	7	11%	3%	5
Light silt loam	14	21	10	7
Fine sandy loam	11	18	5	8½
Clay	16	30	17	7½



The superb soil conditions produced by intensive deep tillage are nowhere of more value than in orchards of citrus trees. These two trees, both Valencia orange, both 15 years old, were planted side by side. The one in unbroken soil is only 8 feet high. The other is nearly three times as high and more than twice as broad. (E. C. Franzen, Santa Ana, Cal.)

These soil types are named for purposes of illustration. The moisture content of other soils can be judged from these figures.

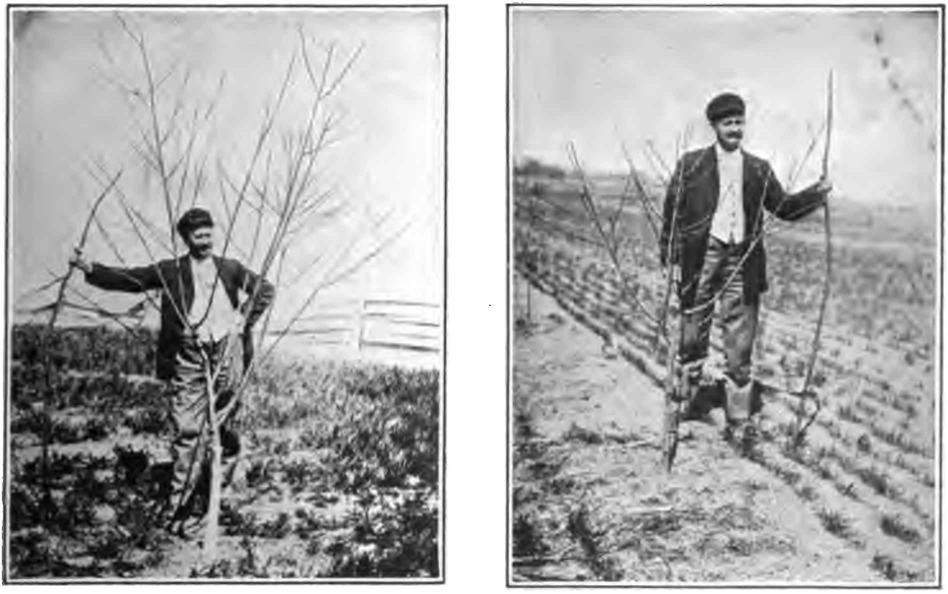
Not All Soil Water Can Be Used

The figures in the first column indicate that clay and light silt loam to a depth of 4 feet might contain enough water for average crops of fruit, while in coarse sand and fine sandy loam trees would run short. But only part of the water can be used. In clay soil, for instance, trees will wilt when the ground still contains about 17 per cent. of water. This leaves only 7½ inches in depth of water out of the total supply of 16 inches when the soil is filled to capacity, that the trees actually can use. The proportion of water that can be used in the other soils is shown likewise in the table.

How Water is Stored in Soil

It follows that all the water that can be stored in the top 4 feet of any soil is not enough for a fair crop of fruit. The supply must be increased. The trees must get a part of their supply from the subsoil beneath the 4 foot level. This brings us to a consideration of the manner in which water is stored in the soil and the ways in which it moves about. In previous reference to the pore space or air space in soil (page 114), the free drainage of excess water was mentioned. Water which will percolate and seep down through the pores of the soil owing to the action of gravity is harmful to all fruit and ordinary shade trees. The roots cannot or will not take it up in this form, and are damaged by it.

The only form in which roots take up water is when it clings to particles of soil as films. This is called capillary water, because it is held to the particles by capillary force. What this force is and the form in which the water is held can be illustrated better than described. Put your finger in water and



A tree should show greater proportionate superiority owing to intensive deep tillage in its second year than its first after planting. This is on account of the roots penetrating deeper and wider in the broken soil, and the increased plant food released and made available. Tillage merely starts the beneficial soil processes. Time is needed before the results show. The two trees shown here demonstrate this truth. Both are at the end of their second year's growth in their present beds. One bed was blasted; the other not. (Fred W. Miller, Millersburg, Penna.)

it comes out wet. Put it in quicksilver, and it will come out dry. Some of the water is held to the skin by capillarity, but none of the quicksilver is so held.

After excess water has drained away from the soil particles, they are wrapped in films of water which can be more correctly called moisture. This moisture is held to them by capillarity until it is taken away by evaporation or by roots.

If one particle should happen to have less moisture than its neighbors, capillary force causes some of the bigger supply to creep from surface to surface till the amount is equalized throughout the soil. The movement of capillary moisture is not limited to the one direction—downward—as free water is limited. In this form moisture moves upward and sideways as well. The movement can be illustrated by the movement of oil in a lampwick, or of ink in a blotter.

Now the movement of capillary water toward the surface from a depth greater than 4 feet is free and abundant when soil conditions are right and there is an abundant supply below. It, however, depends on the fineness and arrangement of particles and the pore space of the soil. The soil must be fine; the particles must touch one another; but they must not be so packed or jammed together that the pore spaces are squeezed shut. If the particles are round, they should touch one another only at minute points on their surface, as apples touch when properly packed in a box. The logical way of feeding moisture to trees or plants is to send the roots down after it. Capillary movement, however, brings the moisture to the roots as they use up the supply they are in contact with.

The reason behind the necessity for a comparatively loose condition of soil is easy to see when we remember the films in which moisture is held. Reduce the surface space of the particles and we reduce the surface area which can carry moisture films.

The size of the particles governs directly the extent of the surface area in a given bulk of soil, and consequently the amount of film moisture it holds.

Film or Capillary Moisture Supply

As it is illustrated often, a solid rock in the form of a cube, measuring 3 feet high, 3 feet wide and 3 feet thick, has 54 square feet of surface area. Reducing such a rock to pieces measuring an inch on a side increases the surface exposed to nearly 2000 square feet. Reducing the pieces to the size of soil particles increases the area in proportion.

As applied directly to the soil, the facts regarding the number of particles and their surface area are striking and wonderful. The table below gives the figures.

Number of Particles and Area of Their Surfaces in Different Soils in Good Tilth

Soil	Number particles per pound of soil	Sq. ft. surface area per pound of soil	Sq. ft. surface area per cu. ft. of soil
Coarse sand	1,326,600,000,000	405	40,500
Medium sand	1,724,700,000,000	473	44,500
Sandy loam	2,914,000,000,000	816	66,600
Silt loam	4,287,000,000,000	1340	104,000
Clay loam	6,811,400,000,000	1825	136,500
Clay	8,231,100,000,000	2000	142,000

The significance of the figures in the last column will be plainer when it is recollected that an acre contains about 43,000 square feet. Each cubic foot of medium sand contains about an acre of surface of particles on which moisture film can be held, and each cubic foot of clay contains upwards of 3½ acres of such surface. Therefore an acre of soil to a depth of a foot may contain upward of 43,000 to 140,000 acres of moisture film when in proper condition.

The figures are illuminating in respect to the varying moisture-holding capacities of different soils. Sand has less than one-third of the capacity of clay. These differences should be kept in mind.

The Moisture Supply Depends on Depth and Thoroughness of Tilth

Good Tilth

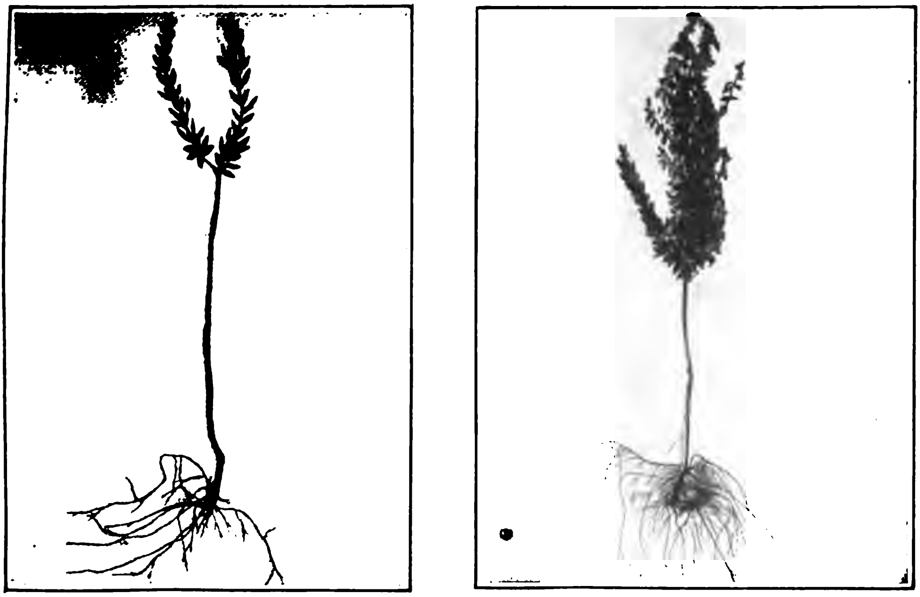
The figures for the amount of water soil can hold are based on soil in first-class condition of tilth, with normal porosity of 30% to 50% and with the usual amount of organic matter. Soil that is compacted, cemented, run together or lacking in humus will not have anything like the stated amounts. Also the movement of water—the drainage of free water and the movement of capillary water in dry weather—will be restricted very greatly.

Emphasis must be placed on this matter of organic material in the soil. It constitutes one of the most important elements that go to make good tilth. If organic matter is lacking the soil will run together and within 2 or 3 years will become harsh and unpleasant in spite of the most intensive tillage.

Organic Matter and Moisture

The way to insure the necessary 15 inches or more of net depth of water needed to grow full-sized crops is to fine and loosen the soil thoroughly to a depth of 4 feet or more in order to store the maximum of moisture, and then have the ground below this depth in such condition that capillary moisture will rise without restrictions.

Tillage must be thorough and deep to promote drainage and to put the



One tree grew from spring to fall in blasted ground; the other alongside it in unblasted ground. The trees both are Yellow Transparent, 2-year when set out, and of equal size then. (E. G. Sexton, Canton, Ga.)

Deep Tillage Demanded

soil into condition to store sufficient moisture. If it is not the soil below the furrow depth becomes compacted and hard. The particles of soil run together till their water-holding capacity is only a faction of what it ought to be and can be under normal conditions of tilth.

Subsoil Plowing

Something can be done toward increasing the moisture storage capacity of soil by breaking to a depth of 16 or 18 inches with subsoil plows and deep tillage implements. But the execution done by proper blasting is better in proportion to its increase in depth.

Blasting Soil

Thoughtful orchardists will see that there is no practicable way of getting the soil worked and loosened at sufficient depths other than by blasting it. Blasting will do it—and in connection with regular and cover crops to keep up the organic matter will insure each season a supply of moisture sufficient for heavy crops in dry weather.

In case layers of hardpan or clay interfere with the movement of water, they should be broken up. Soil should be examined thoroughly for any such conditions.

Surface Mulch Required

The conservation of a moisture supply by shallow surface tillage is a general practice. It need not be described here other than to say that a 2 or 3 inch layer of loose, dry soil or dust will isolate the moist soil beneath and prevent the escape into the air of the water it carries. Deep tillage will help to provide the storage of a supply of water, but it will not conserve it. This moisture conserving (mulching) tillage on the surface is absolutely necessary.

But no amount of surface tillage will conserve moisture that is not stored in the soil. Enough rain falls during the growing weeks of some seasons to supply the needs of heavy crops, but every orchard in which the soil is not deeply tilled is bound to suffer from drouth frequently. The outstanding fact is that deep tillage is required before an adequate supply of moisture can be assured every summer.

How Deep Tillage Increases Fertility

The proper proportion for the different plant foods previously mentioned in the soil cannot be stated exactly, because different plants and trees require different amounts. A slight excess of any element will do no harm.

Balancing Plant Foods

The so-called chain theory of plant food needs has been proved true so often and so extensively that it is to be considered no longer as a theory, but a fact. Briefly, this rule is to the effect that the thrift or growth of a tree or plant is governed by the amount of that plant food in which the soil is weakest, proper balancing considered.

If a certain soil contains—we will select arbitrary figures for the sake of illustration—in each cubic foot 6 units of nitrogen, 10 units of phosphorus and 20 of potash, while the need of the crop grown in this soil is 10 units of nitrogen, 20 of phosphorus and 12 of potash, the crop will not be a full one. It likely will be three-fifths of normal size, because growth will be held down by the lack of enough phosphorus and nitrogen. The oversupply of potash in the soil is of no use because one plant food cannot be used to any practicable extent in place of another.

This one illustration is enough to make clear the idea of the necessity for having all plant foods present and available in abundance. There is nothing mysterious in the fact of a crop failure, nor need there be much doubt about what constitutes proper fertilizing of land.

But knowing what elements of food are needed is only half the battle. It is equally important to know *where to get the necessary material and how to make it available for roots, certainly, cheaply and quickly.*

Plant Foods of the Soil

As stated on page 106, the usual orchard soil contains an abundant supply of available plant foods, excepting only of nitrogen, phosphorus, potash or lime, which may or may not be present in sufficient amounts.

The nitrogen can be secured in unlimited quantities from the air and put in the soil by proper use of legumes.

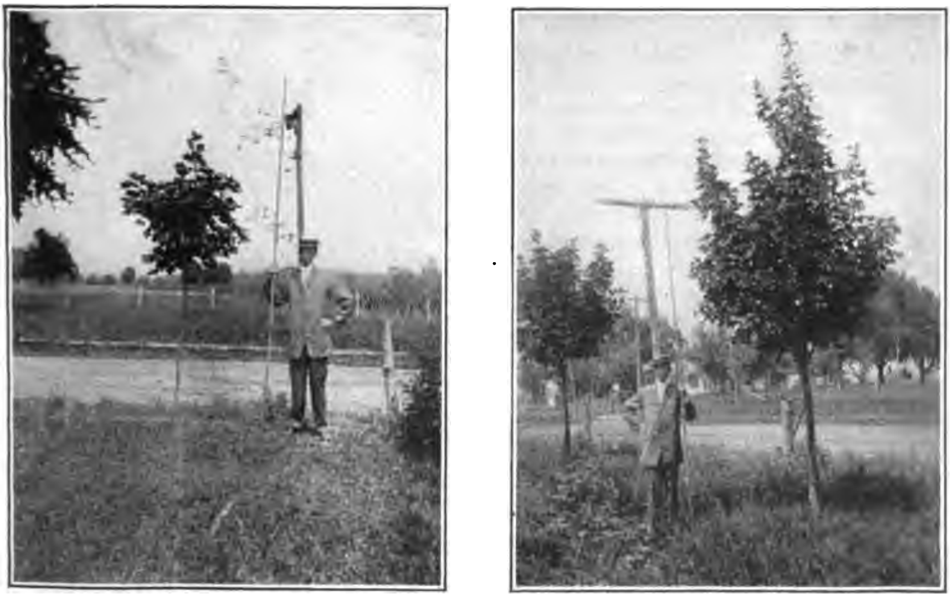
The lime must be added in the usual way.

The Phosphorus and Potash Problem

A chemical examination of your soil, to a depth of 1 to 6 feet or more, if it is clay, loam or sand, likely will show figures for the amount of potash and phosphorus present that may surprise you. To make them apply more easily to the usual field condition, the following data are based on an acre, but of course do not apply accurately to all soils.

Amount of Phosphorus and Potash

The amount of potash in the soil of "new ground" to a depth of 7 inches, the usual furrow depth, will run as high as 60,000 pounds. It may be as low as 20,000, but it will average up to 40,000 to the acre. The soil to a depth of a foot, therefore, contains more than 100,000 pounds, or 50 tons of actual potash. To a depth of 4 feet the amount is 200 tons to each acre.



The growth of shade and ornamental trees is governed by exactly the same principles as that of orchard trees. They must have enough moisture, nitrogen, potash and phosphorus, and must have root anchorage and feeding space. In a yard or lawn the soil conditions are such usually as to be benefited particularly by the intensive deep tillage given by blasting, as these two pictures demonstrate. (St. James, Mo.)

The amount of phosphorus is smaller, but still is formidable. It runs as high as 25,000 pounds to the acre in 7 inches deep of soil in some of the better new lands, falling to only a few hundred pounds in poor lands. In all new lands in good tilth it will average around 8,000 pounds to the acre in the clay, and about 2,500 pounds in loam. In soils that are run down the phosphorus usually is used up till less than 1,000 pounds and sometimes only 200 pounds to the acre remains in the top 7 inches.

Taking the above average figures, each foot deep of fertile loam contains upward of 2 tons of actual phosphorus and each foot of clay, 8 tons. Four feet of soil over an acre contains 8 tons and 32 tons respectively.

Amount of Plant Food Used by Trees

The different fruits and other crops require varying amounts of plant foods, as mentioned at the beginning of this chapter, but a sufficiently clear idea of their average requirements can be secured by examining the demands of a wheat crop. Wheat requirements are not essentially different from those of apple, peach and pear trees.

Trees use the most of their potash and phosphorus in growing leaves, twigs and bark, and little in growing the fruit. The food elements in the leaves of trees, of course, are returned to the soil each autumn, but those used in making wood are permanently removed from the soil.

Erosion and leaching take away some plant food. This loss, of course, must be added to the amount carried away in crops. Tests have shown the loss to be about one-eighth of the amount consumed by average crops. Nearly all of this comes from the few top inches of soil. The top inch or two of some soils is leached "dead."

The store of phosphorus in the soil, we have seen, is much less than that of potash—averaging one-half to one-fifteenth as much—but the amount consumed and carried away by crops is nearly equal. Therefore, the phosphorus supply is subjected to a much greater drain in proportion, and will be exhausted in much less time. In many soils it is already seriously depleted, if not practically exhausted.

Natural Plant Foods Insoluble

In the chapter which described the formation and nature of soil, it was pointed out that heat, cold, water, air, bacteria and other natural agencies had manufactured the loose earth commonly called "soil" by disintegrating and

It is extremely important that an evergreen tree should have its roots below frost-line, on account of the evaporation of water from its needles during the dormant period. Cut off evergreen roots from moisture and they quickly dry out. The resin in their sap hardens. When this happens the tree is doomed, because the sap never again will soften and flow.

decomposing rock. That is, they broke it down from solid rock to the softer stage, of more or less fine particles.

Now, plants require their food to be dissolved in water before the roots can take it up. They take their potash and phosphorus and nitrogen and other foods as soup instead of solids. *But these food elements will not dissolve in water as they exist in the soil.* They first must go through certain chemical changes.

The agencies which produce the changes are the same ones which brought along the processes of decomposition of the original rock so far—water, air, bacteria and the others that have been named. To these may be added organic matter and lime. In the ordinary course of events in an unworked soil, such as in a forest or a field only plowed, the subsoil is but little disturbed and none of these agencies is permitted to do much work. An occasional root penetrates deeply, a mole or a squirrel or other animal may dig a tunnel, producing the conditions necessary for the liberation of the insoluble food. But in the main the freeing of the locked-up elements takes place at a very, very slow rate.

The problem of the orchardist is to hasten the processes of liberation so that the natural chemical changes of dozens of years will take place in one season. To accomplish this he has only to expose the particles of the soil to the action of his helpers, the water, air, lime, organic matter and bacteria. Moisture liberates plant food directly by dissolving such of it as will yield, but whenever there is excessive free water some of the food that is liberated is carried away with the surplus water that drains out of the soil and some more of it is changed back to unavailable forms.

Liberations of Natural Plant Foods

The most rapid liberation of insoluble foods takes place when the water in the soil is limited to the moisture held by capillarity. This water wastes none of the material it frees. Each soil particle contains some of the plant food and its film moisture extracts this and holds it until the roots get it by taking up the moisture.

This picture is included to show what may be considered as standard good growth. The tree, a Stayman apple, was planted in Maryland, near the Pennsylvania line, late in April. The photograph was made in September. The average growth of branches is 18 inches. (Garacove Farm, Northeast, Md.)

Air produces oxidation of the insoluble elements (as rust) in connection with a proper supply of moisture. Organic matter contains acids, which, released in the decomposing of the roots and leaves, act chemically on the locked-up food in the particles and free some of it. Lime acts to some extent in a similar way. But by far the greatest amount of liberation of the insoluble elements is due to the action of certain beneficial bacteria.

These beneficial forms of animal life cannot exist in soil that contains little air, or which has either too much or too little water, or little vegetable matter. Nor can they exist when the soil lacks lime. As soon as the soil is made normally porous, as described on page 114, the excess water drained away and a proper supply of moisture held as films about the particles, and when vegetable matter in the form of roots and stalks of plants is introduced, the bacteria begin to multiply and become very active. Under favorable conditions they are able to liberate more insoluble potash and phosphorus in 1 or 2 years than has taken place in 100 years without them.

On the majority of farms some potash and phosphorus has been added to the top-soil in commercial fertilizers and manures, but the quantity is small compared to the original natural supply.

Recapitulating, the liberating of the insoluble potash and phosphorus that is in the deeper soil calls for the introduction of air and the presence of capillary moisture and plenty of organic matter. The only way in which the moisture can be stored and maintained in dry weather, is by fining and loosening the soil, which automatically brings the necessary porosity and air supply and conditions for root penetration.

The presence of a large weed and grass growth proves that the soil is fertile. It is not detrimental, but helpful, in the orchard after July. Under a system of shallow surface tillage during the spring months and intensive deep tillage every few years the food supply will be kept up largely by nature.

The difficulty in an unworked soil is to keep plant foods, particularly potash and nitrogen, in an available condition. When bacteria are not active, the available fertility reverts to its original insoluble state very quickly.

Cover Crops

Once the soil is loosened, cover crops should be planted immediately so that the ground will be filled with roots to a depth of 4 or 5 feet. This is the only way raw vegetable matter can be distributed below plow depth. Tillage itself will not make the soil granular and mellow. That is a result which comes about after proper conditions are established. The proper plants to select for this purpose are those which have abundant roots. If the regular crops meet these specifications they will do.

Weeds make good cover crops. Some of the more common weeds, such as wild carrot, ragweed, smartweed, mullen and others have the power to take from soil—even sandy soil—larger quantities of potash than cultivated grasses or crop plants do. They break down insoluble plant foods and store a heavy percentage in roots, stalks and leaves. On their return to the soil these stalks and roots serve the double purpose of organic matter and of carriers of available food. Throughout preceding pages no attention has been given to this power of plants to act as miners and refiners of insoluble native food elements in the soil. Their action in liberating locked-up elements is considerable.

Methods of Tillage

To discuss the methods of loosening and fining the soil would be only to repeat what has been said in previous chapters. It can be done with a certain degree of effectiveness with deep tillage implements and subsoil plows, but it can be done better by blasting. The explosives reach down where the tools cannot reach—with a thoroughness beyond comparison.

Soil

The vital point is to get the subsoil at depths below a foot worked thoroughly. To depend on the soil above this is to send a boy to do a man's work. The use of 3 or 4 feet of soil by the roots, rather than 7 inches, or one foot, obviously is bound to be of great advantage unless the top foot is exceptionally rich. The rate of liberation of the insoluble elements from one foot of soil seldom is great enough to provide food for the full crop. From 3 or 4 feet the amount liberated at the same rate will be 3 or 4 times as great, and is more likely to satisfy the trees.

Lime improperly applied will cause the soil particles it comes in contact with to give up all their plant food, and it will decompose organic matter very fast; hence its use should be planned carefully. Burned lime, either steam slaked or air slaked, is much more violent in its action on the soil particles than ground limestone. The latter is mild and slow when applied in any quantity; the former should be strictly limited in quantity and should be thoroughly and evenly distributed and mixed with the soil.

In soil that is properly porous and fine, lime applied to the surface is carried all through the ground to a depth of 3 or 4 feet within a comparatively short time. In compacted soil, as when the ground under the usual furrow depth has not been broken up for years, lime organic matter and rainfall—and roots—are kept near the surface while ground moisture and seven-eighths of the plant food that ought to be used are kept below, safely and uselessly—stored for the benefit of future generations of farmers.

This peach tree is a product of intensive deep tillage. It was planted in its present bed one year and six months before the picture was taken, consequently it made the growth you see in two seasons. (R. C. Walton, Fruit City, Mo.)

The Nitrogen Problem

The relation of deep tillage to the supply of nitrogen in the soil is not so direct as to the supply of phosphorus and potash, but none the less definite. Tillage, together with proper accompanying orchard practices, will keep the soil supplied with all the nitrogen the trees need.

In Chile are deposits of nitrogen-bearing mineral, which, in the form of nitrate of soda, is used in

Nitrogen in Commercial Fertilizers

fertilizers to carry nitrogen into the soil. Other commercial fertilizers bearing nitrogen are cotton seed meal, bone, meat scrap and dried blood. In them the nitrogen costs 12 to 40 cents a pound at usual market prices. This nitrogen is an exceedingly expensive plant food compared with phosphorus, and compared with the value of the growth it makes, though its use in these high-priced forms may be profitable when well directed.

Nitrogen in the Air

A cheap source of nitrogen, however, is the air. The air is 75% nitrogen. Over each acre of ground there is an unlimited supply of it. The cost of getting nitrogen from the air is small. In many cases enough other benefits are derived from the process to give a profit in addition to the nitrogen. Probably it is better to say that the processes which produce the nitrogen are required anyhow in nearly the same form to establish and maintain good soil structure and texture.

This atmospheric nitrogen gets into the soil as one of the components of organic matter—in leaves, stalks, roots and seeds. The plants which are richest in nitrogen are the legumes—clovers, peas, beans and vetch. But all plants contain some of the valuable substance.

Amount Used by Orchards

The amount of nitrogen needed by orchards will likely be 50 to 150 pounds a season. Heavy crops of corn require 150 pounds. Light crops of wheat require as low as 48 pounds. The cost of these quantities of nitrogen if all is bought at current prices in commercial fertilizers is prohibitive.

Soil Supply Dissipated

In the usual soil there is but little nitrogen. A chemical analysis likely will show a few hundred pounds to the foot in depth over each acre, though soils unusually rich in organic matter may contain several thousand pounds. But unlike insoluble potash and phosphorus, on the ordinary farm nitrogen soon becomes soluble in the top foot of soil. When the leaves, stalks and roots carrying it decay, it is liberated, and in the free state any surplus not taken up by roots leaches away and is lost within a few months. On this account the supply in the soil can be kept up only by adding to it every year or so the quantity taken out by the trees and lost through incidental leaching.

Amount in Legumes

The legumes gather more nitrogen from the air than other plants because of certain bacteria which accompany them on their roots, and without which they do not thrive. A ton of legume hay contains about 40 pounds of nitrogen. The different legumes vary a little in content of nitrogen, and in the amount carried above and below the ground. But in general it is near enough correct to count that every ton of dry plant growth of clover, beans, peas or vetch—roots, stalks, leaves and blossoms—will give you the 40 pounds of nitrogen. Since an average crop of these plants is a couple of tons or more, their annual use as cover crops will increase the supply of nitrogen against all losses without the addition of large amounts in commercial fertilizers.

Legumes get a large part of the nitrogen they use from the air and a smaller part from the soil. Before they will succeed, the soil must contain a little nitrogen and must be loose and porous. In a soil that is harsh and devoid of practically all nitrogen the start should be secured by first using lime and then turning under rye, or some other plant that will provide organic matter, thoroughly loosening and fining it at the same time. Conditions then soon will be such as to permit of the successful growth of good crops of the more valuable plants.

It is the top-soil that under usual conditions of shallow tillage contains practically all the nitrogen. The subsoil contains little or none. The reason is that most of the organic matter carrying the nitrogen that is turned under is placed in the bottom of the furrow, or is distributed from this depth upward.

Getting Nitrogen Distributed Deeply

Under any tillage system, the bulk of the organic matter put into the soil must be merely plowed down. It cannot be mixed with the deeper soil immediately, except in the form of the roots that penetrate deeply and that carry down much nitrogen. It is not long before deeply broken soil becomes impregnated with a small amount of nitrogen as far down as it is loosened and powdered. This cannot help being of great advantage to trees, the roots of which occupy the lower soil rather than the top 7 inches. When the trees are compelled to get all their nitrogen out of the top few inches, or at most the top foot of soil, in orchards worked no deeper than the plow goes, they seldom get all the nitrogen they need because only part of their root system can get at it.

Loose Soil Prevents Leaching Loss

Too much stress cannot be placed on the value of a deep layer of loose, fine soil as a filter-bed that will catch escaping nitrogen and other plant foods. The excess water that percolates through 4 feet of fine soil particles loses much of any burden it carries, and this salvaged material is deposited deeply, where it is relatively safe from further leaching as well as convenient to roots under proper condition.

At Lynchburg, Va., blasting the soil for shade and ornamental trees has become a recognized practice. Notice the excellent growth of new wood on the ends of the limbs of this elm.

Tillage Helps Nitrification

It should be understood that free nitrogen is not taken right out of the air and fed directly to roots. It has to go through 3 or 4 chemical changes before it reaches the stage in which roots can take it from the moisture films in the soil particles. These changes, known to agriculturists as nitrification, are important in this discussion only because they require air, capillary moisture and bacterial action.

The process of nitrification is much hastened when soil conditions are good. *In fact, in soil that lacks air and which is either very wet or very dry, it is difficult to keep nitrogen in an available form,* no matter how much organic matter may be present. It either is liberated and escapes, or it reverts to an unavailable form. This is illustrated in muck and peat, soils that are almost entirely composed of the remains of plants, rich in nitrogen in an insoluble form. Therefore, adequate supplies of free nitrogen are to be found only in soils that are well and deeply worked.

The methods of working the soil are unimportant, so long as they are thorough and effective enough. Deep tillage implements will do good work to a depth of 18 inches under favorable conditions. Blasting will do even better work to any required depth. The repetition of the full discussions of this matter on pages 114 and 120 is not necessary here.

Methods of Working Soil

During years past some friends of soil blasting have claimed for it certain other advantages that never have been proved. It is unnecessary and undesirable to list them in this bulletin, for no exact data are available on which to base conclusions. Furthermore, whether or not such claims are true is of little importance, because of the overwhelming value of the direct physical tillage action of proper soil blasting, which cannot be questioned. *Soil blasting is intensive deep tillage.*

Treatment of Different Soils

Practically all clay and loam soils respond wonderfully to tillage blasting, requiring only the addition of lime, the required fertilizers and cover crops, of course, to make them produce record-breaking crops. But there are a few soils that differ in nature from clay and loam to such an extent that intensive deep tillage is of no benefit to them.

One way of making clear the proper treatment for each soil would be to describe every important soil in the country, giving its nature and suggestions for exactly the sort of tillage best suited to it. For instance, we might describe limestone soils, redshale soils, sassafras soils and so on down a long list, making clear the types of each soil. This, however, would be a cumbersome way of going about the matter.

Lynchburg, Va., where a great many ornamental trees are set in blasted ground. These trees show by the amount of new growth exhibited in the pictures that they have plenty of moisture and food.

Soils are classified by the Government and by agricultural authorities largely according to their origin, as is illustrated in the ones named above. Yet to the practical orchardist, with a practical problem in fertility and moisture supply to solve, the vital factor is first the size of the particle and second the condition of the soil with respect to amount of organic matter present in the particular land he has. Therefore, it seems that the things to talk about here are the structure, texture and condition of soils, rather than their origin.

About 10 types, or degrees of fineness of particle, usually are recognized, ranging from pure clay, through various degrees of silt and loam, to pure coarse sand. The clays have the finest particles; the sand the coarsest. As a general rule it can be said that the smaller the particle of the soil the greater the benefit it will derive from any sort of intensive tillage.

The fine particles seem to give up their natural fertility easier than the ~~coarse ones~~—they respond more to proper cultivation. As the size of the particles increase, less and less plant food will be released from them under any conditions, and less and less improvement will be made by intensive tillage in the drainage, moisture storage capacity and nitrogen supply.

When the particles reach the size of SAND and especially COARSE SAND, with little or no clay or loam added, the soil has all the porosity it needs and the particles are located so as to give their greatest surface area per cubic foot of soil when the ground is packed about as hard as it ever gets. To loosen up such a soil decreases its moisture storage capacity, already low, without any other effects. Such coarse-grained soils should not be blasted.

Muck Soils Are composed of the remains of plants mixed with sediment deposited by standing water. The material remains muck instead of decomposing further and becoming loam, because of the absence of air and bacterial activity. They should first of all be drained of their excess water by proper ditching. This will leave them porous enough for best results without further loosening.

Clay Soils Vary greatly in structure and condition. Their moisture holding capacity is high, and they usually need draining. Some of them have clay and nothing but clay, compact and practically water-tight from top-soil to a depth beyond the reach of roots. Such a clay soil should be broken up and fined to a depth of about 4½ feet under ordinary circumstances, as this is about all the depth that can be kept open and porous.

While in some clay soils the layer of clay may be thin—often only 6 inches—in others it is 3 or 4 feet, or even 5 or 6 feet thick. Under the clay there is often a layer of gravel or sand. Such soils should be *broken up* clear to the bottom of the clay layer, and if the clay is thin and near the surface, the breaking should extend into the layer of earth under it, at least through a total depth of 4 feet.

Loam Soils Also vary greatly in structure and condition, but almost universally they require the same sort of deep tillage for planting trees. They should be fined and loosened to a depth of at least 4 feet. Occasionally loam should be loosened deeper, on account of need for drainage. The subsoil of long-cultivated loam generally is very much compacted. These soils usually are fairly well drained naturally, but may require special attention in this respect. Coarse sandy loams and gravelly loams seldom require deep tillage.

Hardpan, Cemented Gravel, Bound Loams and Sands And other layers of tight soil may be found in either clay or loam, and sometimes even in sandy ground. The particles of the hardpan usually are very fine. This layer of compacted and hardened material may be as thin as 3 inches or as thick as 6 feet. It should be broken entirely through in every orchard where found.

Stony Land Does not differ in tillage requirements from soil without stones. The stones seem to help in moisture storage a little, and in orchard soil are not regarded as a detriment if they are small.

How to Blast Orchard Soil

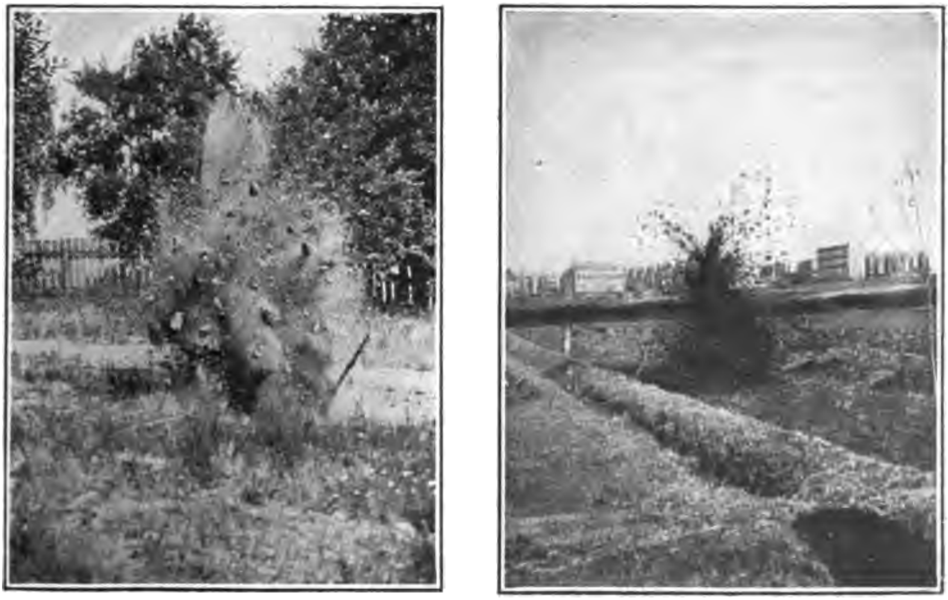
Proper preparation of ground for planting trees is little different from correct tillage of orchard soil between and under growing trees. The principles are the same and the mechanics of the actual blasting differ but little.

Soil Must be Dry

The first care in every case must be to see that the subsoil is dry. THE SOIL SHOULD BE AS DRY AS POSSIBLE—the drier the better. Unless the subsoil is so dry that it has but little plasticity the action of an explosive will not give the maximum quality and quantity of tillage results.

The reason why soil cannot be blasted with proper results when it is damp or wet is easily shown. Strike a wet clod with a spade. Instead of loosening under the pressure the clod becomes compact and makes a solid lump. Now strike a dry clod in the same way and you will crumble it. If it is very dry you will pulverize much of it into dust. Damp and wet soil becomes compact under pressure. Dry soil crumbles.

If ground is wet or quite damp when it is blasted, the effect is only to make a ball-shaped hole 2 or 4 feet underground, more or less covered with loose earth. The soil for about a foot on all sides of the immediate spot where the charge of explosive was located will be compressed instead of shattered. The sides of the hole, so formed, and the bottom, will be tightly packed. A few cracks may extend into surrounding soil, but 95% of the effect of the blast will be confined to a sphere 2 or 3 feet in diameter, with positive packing instead of loosening. THIS IS NOT GOOD SOIL BLASTING. It will not give the benefits that have been described in previous chapters of this bulletin. Except in isolated instances it will disappoint anyone who tries it with the expectation of good results.



These two pictures are included to show two things. One: how *not* to blast tree beds; never permit the blast to blow dirt out, as these blasts are doing. Keep the amount of the explosive reduced to the point where the surface of the ground will be only heaved. The other: how a blast crumbles dry soil; the ground is drier in the left-hand picture, hence the soil crumbles to dust. You can see the stones among this soil, in the air. In the right-hand picture the soil is damper, and does not powder as well. See pages 103 and 104 for other pictures.

The conflicting results from "soil blasting" which have been noted in various orchard experiments and tests, and about which much discussion has been aroused, have been due largely to variation in the condition of the soil at the time of blasting. As might be expected with a new process, the methods of practice have not become standardized. There are as surely right ways and wrong ways of blasting as of plowing. Much of the blasting of the past few years has been done in ways that in the light of present knowledge could be expected to give but little if any benefit.

When the soil is dry at the time of blasting, the effects of the explosion reach out many times further than when it is damp, and the breaking and fining action of the gases is much more thorough and complete. If any cavities are formed underground they can be easily filled by running a shovel into the bed of the blast. In actual planting, the loosened dirt should be shoveled out.

When to Blast

In respect to the time or date of blasting, good results are derived when the work is done just before the trees are planted—provided the ground is dry. It is rather difficult, however, to bring the two operations together while doing both justice.

Trees usually should be planted when the ground is damp or wet. You can plant trees in dry ground successfully, however, though you cannot blast wet ground successfully under any circumstances. If you plant, in dry ground use two or three gallons of water about each tree.

Spring usually is the best season to plant in the North, but blasting ground in the spring before too late to plant trees is a matter of luck. Proper conditions occur at that season only once in several years. Sometimes you can do it; more often you cannot. Fall planting usually is not advisable in the North, though in the South it often is to be preferred. In fact, in the South, planting can be done successfully without interruption from the time the leaves drop in autumn till the buds open in the spring.

All things considered, blasting of orchard soil usually can be done to the best advantage in July, August or September, after a prolonged rainless period of weather. Sometimes the ground is dry enough in May or June; once in a while it is dry enough in October or later in the fall.

Blasting soil in the summer or fall for planting the following spring is entirely successful. The plan has many advantages. The action of sun, air, frost, water and other agencies during the winter on the loosened soil results in much increase in its fertility and cavities made by the blast become filled. A cover crop should be growing during the fall months in the blasted ground, whether the tree is planted or not.

When planting must be done in the spring and the soil blasting has not been done the previous fall, it is all right to blast if the subsoil is dry, and will conform with the tests given on page 131, but if it is wet, the better plan is to plant the trees without blasting, then to blast the soil about them during the following summer. This can be done with satisfaction. The details are explained on page 137.

Depth for Charges

The proper position of the charge in the soil depends on the nature of the soil. It should be deep enough to break the soil down 4 feet, and in many cases the effect of the blasting should extend deeper, even as deep as 6 or 8 feet, but such depths of blasting are advised only for a few kinds of trees. Individual comments on certain soil conditions are necessary to make clear the proper depth for charges.

It must be understood that intelligent placing of charges depends altogether on examination of the soil with an auger or by digging. Without the tests it is guesswork.

Hardpan

The proper depth of the charge depends on the thickness of the hardpan layer. In any case the soil should be broken to a depth of 4 feet. Usually, the layer of hardpan is so placed that the charge should be located about ⅔ of the way down through it.

In case the layer of hardpan is thicker than 4 or 5 feet, it is almost impossible to break it entirely through at a reasonable cost. The charges should be placed in such soil about 4 feet deep with the object of loosening and fining a section of the soil 4 feet deep, leaving the underlying hardpan intact. But it is best to break the hardpan entirely through to a softer, more open layer of earth underneath when practicable.

When there is loose or open ground below a relatively high and thin layer of hardpan, the charges of explosive should not be placed so near the bottom of the layer that the force of the explosion will escape into the loose ground below and only break the hardpan into large chunks instead of crumbling it. The remedy is to locate the charge higher in the hardpan, but do not place the charge so high in the layer that the blast will break through to the surface of the ground without shattering the hardpan to softer ground below.

CEMENTED GRAVEL and other tight, bound soils usually lie in layers similar to hardpan, and should be blasted in a similar manner.

Clay

Clay soils may be composed of solid clay or the clay may lie in thin or thick layers. Also the clay may be near the surface or may be covered with 1 or more feet of loam or sand. When this occurs, the clay, if less than 4 or 5 feet thick, should be broken through to more open soil beneath. The placing of the charges to do this is precisely the same as in hardpan, as described in the previous paragraph. Where a thin water-tight layer of clay occurs 4 or 5 feet below the surface, the charges should be placed right down on the clay, in order to break it through.

A typical tree in the orchard of H. M. Magee, Waynesboro, Va. Planted in 1901 in a blasted bed, it began fruiting in 1907, yielding 1½ bushels when 6 years old. The following years its yield was 2¾, 3, 10½, 12, 14 and 13¾, until 1913. The picture shows the condition of the tree in respect to growth.

Loam Soils

Loam soils, of all kinds, offer simple problems. They may or may not have a plowsole. The subsoil may be loose or very compact. In any case the charge should be about 3 feet deep. Loams containing a large amount of fine earthy sediment are benefited by loosening and fining, but the charges should be placed well to the surface—say within 2 or 2½ feet in depth. When the subsoil is heavy, as when of distinctly clay nature, the charges should be placed a full 4 feet deep.

Shale and Slate

Shale and slate surface soils, whether of clay, sand or loam type, often are underlaid with rock. This rock may be brittle and soft, and may be broken up to give more root space. Place charges in the rock as deep as 18 inches below the last of the loose soil. The charges should be heavier than for blasting hardpan.

Size of Charges

The amount of explosive to use in each charge must be governed by the depth at which the charges are placed and the hardness of the soil. A strongly cemented hardpan, for instance, will require almost double the charge that is proper for a relatively light soil. Clay, when heavy, requires almost as much explosive to the charge as hardpan, though it shatters under much less force when it verges close on having a loamy nature.

Fortunately, no doubt is necessary about the correct size of the charge for any particular soil, as there is an unfailing rule which determines the correct amount of explosive to use. *After you have made sure of the proper depth for the charge by boring or digging into the soil and locating and identifying the various layers composing it, use just enough explosive at this depth to break the ground to the surface without blowing out a crater.* The surface of the ground should be heaved and lifted, especially showing a bulge over the charges, but very little of the ground should rise into the air at the time of the blast. When the ground is quite dry the explosion will create considerable dust, which will float above the surface.

The usual charge for blasting tree beds will be about half a cartridge of explosive (¼ pound) when the charge is located 3 to 3½ feet deep. At 4 feet, ¾ of a cartridge likely will be required. At 2½ feet deep the charge likely will be only ¼ cartridge. These figures should be the basis for making the first test shots, but after the tests *the size* of the charge should be regulated entirely by the *results noted*, as described above.

It must be remembered that some soils require considerably heavier charges than the above stated ones. It is no rarity to find a hardpan condition requiring 1-cartridge charges placed at a depth of 4 to 4½ feet, and certain hardpan and clay conditions require the placing of 2-cartridge or even heavier charges at depths of 6 feet.

In general small charges are more desirable than large ones for tillage blasting or orchards. The usual method of blasting ground for trees is to place one charge where each tree is to stand.

The trend of practice among those who have studied the matter and have had much experience is to use several light charges placed

A soil auger often can be used to good advantage in making holes for subsoil charges, particularly in heavy soil. Holes started to a depth of one or two feet with a bar can be finished easily with an auger.

not very far apart rather than one large charge, to do the same work in preparing the ground for a tree, or in tilling the ground about one. This is particularly applicable in deep clay and hardpan.

Number of Charges per Tree

An explosion is necessarily more violent close to the charge. Its fining and crumbling effect diminishes as the distance from the charge increases, hence 3 small charges placed at the corners of a triangle, or 5 small charges distributed over an area about the point where a tree is to be set, will produce a condition superior to one charge located in the center of the area.

Spacing Charges

The distance between charges is of course governed by the spacing of the trees when only one charge is used in each tree bed. *When more than one is to be used for each tree and when the ground between the trees is to be blasted, the charges should be so spaced as to break up all the ground.*

When 3 or 5 shots or more are used for each tree or tree bed, the spacing between charges should be 6 to 10 feet. In case of blasting the ground between trees the charges can be spaced 6, 10 and sometimes even 18 feet apart. The only way to determine exactly how far it is best to space them is to dig or probe into the ground after 3 or 4 trial shots. Note how far the crumbling and pulverizing effect of the blasts extend and space the charges accordingly.

In ordinary loam the average properly balanced blast will break as far as 8 or 9 feet away, though the ground at the edges of this circle will not be well shattered. When the orchard is large each charge should be relied on for its extreme range, but in small orchards, particularly in home fruit gardens, where economy in the blasting can be a secondary consideration, the soils should be blasted with charges placed from 6 to 10 feet apart.

Making Holes

The holes should be made straight down. Soil that is dry enough to be blasted offers considerable resistance to a bar or soil auger. Ordinarily the subsoil bar will make the hole quicker and with less work. In stony land the bar must be used. Sometimes a good practice is to drive the bar down a foot or a foot and a half, or as far as it will go under a few strokes of the sledge, then use the auger for the rest of the depth. When drilling dry ground with the bar, the hole should be filled with water.

The holes should be loaded in the ordinary way, as explained on pages 148 to 150. Put the charge of explosive in the bottom of the hole, push in about 5

A Mammoth Black Twig apple tree in the Rose Cliff Orchards, Waynesboro, Va., growing in blasted ground. The tree has set a heavy crop of fruit and at the same time made a good growth—see the twig ends. To do this the tree must have abundant moisture and food available during the growing season.

Loading Charges inches of dirt, but do not pack or tamp it, then insert the tamping stick and as you push in more dirt work the tamping rod up and down and close the hole up tight to the surface, being careful not to kink the fuse or the electric detonator wires.

The charges can be exploded with cap and fuse or with a blasting machine and electric blasting cap. When the charges are close enough together to make

Firing Charges the breaking overlap at the time of the explosions, it may be of advantage to fire them simultaneously, owing to the somewhat greater execution developed. This calls for electric firing. When the charges are spaced so far apart that they will not break all the intervening ground, simultaneous firing is of no advantage. Electric firing involves more trouble than fuse firing, and is considerably more expensive.

Kind and Grade of Explosive The explosive to use for blasting orchard soil invariably should be a comparatively slow acting one. Since the ground always is dry, no waterproof qualities are required. Use 20% strength ammonia dynamites.

Time and Cost Making the holes in the ground is the big labor item. Loading and firing labor is small. One man should make and load 50 to 100 or more holes per day in loam or silt soils in good condition. In certain hardpan soils the same man might make less than 50 holes a day.

The cost of both labor and explosives varies so much from time to time and from place to place that to name a definite figure of cost for blasting orchard soil is risky. The cost, however, ought not to exceed ten cents per shot, on a basis of half a cartridge per charge.

Computation of the average cost per acre is inaccurate, because no two orchards will demand the same treatment. By figuring the cost per tree, or per charge, and using the following table to determine the number of trees or charges in an acre, you can arrive at about what the acre cost in your orchard will be. Nearly every fruit grower knows how many trees he has—knows this when he does not know the exact acreage—and the cost for the whole orchard easily can be figured on the tree basis.

	Number of holes to an acre, square method	At various spacings, triangular method
40 feet apart	27	31
35 " "	35	40
30 " "	50	55
25 " "	70	80
20 " "	110	125
18 " "	135	155
15 " "	195	225
12 " "	305	350
10 " "	435	505
8 " "	680	675
6 " "	1,210	1,600

It does not cost less to blast tree beds than it does to dig the holes, though the blasting may save some labor. The soil can be shoveled out of a blasted tree bed quickly, but digging without blasting is a slow job. To make the holes for the charges, to load, to fire and to shovel out the dirt, takes about as much time as to dig average holes.

Blasting Soil in Standing Orchards

To blast the soil in orchards already planted, even when the trees have reached full size, is entirely practicable. In fact, this is one of the recognized methods of renovating and improving old orchards.

Precisely the same principles apply to this blasting as to blasting the soil in preparation for planting trees. The only difference is that imposed by the necessity for avoiding the bruising or tearing of roots. The ground must be dry and the charges must be placed at the depth demanded by the nature and condition of the soil.

Size and Depth of Charges

Ordinarily the best way of going about the work is to put in the ground very light charges (¼ to ½ a cartridge of explosive) at the proper depth about the trees under the end of the limbs. Most of the feeding roots likely end nearly underneath that point. Some of the roots within 12 to 15 inches of the charges will be broken by the explosions, but beyond this range they will not be damaged much or at all.

Trees that have been planted only three or four years will have limb spreads too small to come under this rule. To blast the soil about such trees, keep the charges away about 4 to 6 feet from the trunks. Each tree-bed should be blasted with at least three charges.

About large trees the charges should be spaced 8 to 15 feet apart, in order to break *all* the soil. Possibly the blaster should be satisfied with a little less surface breaking in a standing orchard than an open field or a garden. The correct growing-tree blast will have little visible surface effect. Nearly all of its execution will be confined in the ground 2 or 4 feet underground, or deeper.

It is doubly a mistake to use heavy charges about growing trees. The local effect is too severe. Charges of a full cartridge will break and bruise a good many roots. But the small charges recommended, will not, as a usual thing,

Few well-informed orchardists attempt to start a commercial fruit plantation without making intercrops pay some or all of the expenses of caring for the trees. To do this requires that the land be productive of the crops planted between the trees, and that the trees themselves grow fast and bear soon. Intensive deep tillage helps wonderfully in securing both results.

break roots farther than a few inches. Beyond 10 or 12 inches the ground will be loosened and fined for several feet, without any particular hurt to the roots.

Blast Soil Between Trees

The ground beyond the ends of the limbs of the trees always should receive attention. If you thoroughly and deeply work this soil, the new growth of roots will run out to it within a year or two, accomplishing what you are after without much pruning of the root system. The trees in the average orchard are spaced only far enough apart to permit a maximum development of their root systems, hence you should skip none of the ground between.

When blasting the soil under and about large trees, it often is a good plan to blast on two sides of each tree one summer, and on the remaining two sides the following season.

Blasting Out Craters

In very poor soils the plan of blasting out deep craters between the trees sometimes is advisable. This serves the double purpose of permitting greater root penetration, improving tilth, and giving a chance to establish a reservoir of plant food and moisture by filling the hole up with manure, commercial fertilizer and mellow top soil, mixed together. The roots quickly will find such a feeding ground. Be sure to include a big proportion of vegetable matter—leaves, grass or straw—with the material used to fill the craters.

When to Blast

The season when tree blasting had better be done is when the ground is dry. The only possible objection to August or September blasting would be that it might force a fall growth. To blasting non-bearing trees in July there is no objection, nor can there be any to blasting after the first frosts have come in the fall and the trees have ripened their new wood. For bearing trees, the blasting should be done as soon as possible after the first frost.

Good Orchard Soil Management

Practical orchardists will ask how correct blasting of soil should be fitted into the regular tillage schedule. The following suggestions do not make a comprehensive outline of the orchard tillage subject, but are intended as a series of more or less connected hints on methods of cultivation.

Trees of any age grow faster when well watered and well fed than when either water or food is restricted. The blasting of soil is designed to increase the supply of both, hence should result in bigger trees at any age. Other things equal, big trees certainly will bear more fruit than smaller trees. They have more bearing wood.

Whether or not the trees bear sooner in blasted ground than otherwise is a matter of condition of the trees when they reach 4 or 5 years of age. If they are growing very rapidly they will not bear well. If they are not supplied with proper nourishment, they will not bear. The trees that bear young are those which have grown vigorously during the first two or three seasons, and then receive some sort of check, but which have good food and water conditions. Lack of moisture in late June or early July may throw the growth of a young tree into making fruit buds. Lack of plant food, summer pruning or insect attacks may do the same. In any case, you cannot get early bearing from trees that are not vigorous, hence to put the soil in condition to produce vigorous trees is a step toward early bearing.

The same soil condition is a preventive of insect and fungus damage to trees, in that vigorous trees will not be overcome by an attack of scale, cedar rust or other orchard enemies as easily as or quickly as one that is growing slowly.

In the case of bearing orchards, the man who blasts the soil has every reason to expect larger fruit than the man who does not. It gives the trees a greater supply of moisture to put into the fruit. The growth, health, and vigor of these trees cannot but be improved by the additional supply of plant food made available, and instead of declining and deteriorating, the trees should become stronger and better each year, unless they have already reached a very advanced age.

The need of intensive deep tillage is greatest when heavy intercropping is practiced in the orchard, and it is under such conditions that soil blasting shows its most pronounced results. This is a western scene, but so far as soil and weather conditions are concerned, it might be anywhere in the country that fruit is grown commercially.

If possible, plan for your blasting some months ahead by sowing a heavy-rooted cover crop in the spring. This is not essential, but it is desirable. Do the blasting in the summer or fall. In July or August, if the spring cover crop has not been plowed down before, turn it down and sow another which should occupy the ground until the following spring.

The use of so many cover crops is advisable because organic matter must be supplied in plenty to the soil if the correct soil processes are to be continued, and a proper condition of granulation is to be brought about and maintained. Blasting or other forms of deep tillage and cover crops go together. Blasting is not half so beneficial without the heavy growth of roots as with them.

In the orchard where the clean cultivation system is practiced, plow as early as possible the next spring after blasting, and keep the ground harrowed every ten days or after every rain until late in June or early in July. Then sow a cover crop again. The surface mulch of loose soil conserves the moisture while the trees need it. The oncoming cover crop takes up the moisture and hastens ripening of soft growth of the trees at the proper time.

The orchard soil should be limed liberally. The best form of lime to use in orchards is the ground raw stone. It should be applied at the rate of 2 tons an acre every 3 or 4 years. The first application should be made during the summer the blasting is done, though it may be given in the spring before, after the ground is plowed for the cover crop.

The use of cover crops is closely associated with the length of time the effects of blasting will last. The deep tillage opens the soil, let us say, to a depth of 4 feet. Unless there is something to keep the particles apart, each winter and each period of wet weather will see more of them floated together into the former compact conditions, but when cover crops are sown the roots go down to the bottom of the layer of loosened ground, and act as lightening to the soil, making it more and more loamy. When practicable, be particularly careful to get a good heavy stand of the cover crop plants close up to the trunks and all about under the limbs of the trees.

If the blasted soil is supplied as it should be with vegetable matter in the form of roots and cover crops plowed under every year, there is no reason why the soil should become compact again for 15 or 20 years. Mere mechanical loosening of the soil, whether with plows or explosives, may not keep it loose nearly so long. Probably under average conditions, it will be well to repeat the blasting every 6 to 10 years.

The kind of cover crop is important only in two respects. You must grow clovers, peas, beans or vetch to get nitrogen. You must grow annual, or biannual plants instead of perennials, in order to have dead and decaying roots in the soil rather than living, growing ones. (Weeds, rye, oats, sorghum, millet and many other plants are excellent sources of organic matter).

Any sort of plant will gather and later liberate some locked-up plant food. On this account plants can be called "miners" and "refiners" of slowly soluble plant foods. The fact that they do this is another reason why it is important to have abundant quantities of roots growing deep into the soil.

In grass mulched orchards it is well to plow up the sod every 4 or 5 years in order to force the roots of the trees down from the surface. Otherwise, they will tend to gather just under the grass. The plowing should be done in the fall following the blasting, or the next summer. Soil blasting is especially valuable and beneficial in a grass mulch system of culture.

The fertilizing of orchards under a proper system of intensive deep tillage is a very simple matter. If you grow legumes as cover crops, you will get much nitrogen from the air. Usually, some additional phosphorus, and if available, potash should be supplied. If the trees indicate a lack of nitrogen, by showing yellow leaves and by other signs well known to most orchardists, use a little nitrate of soda, cotton seed meal, or other heavy nitrogen carrier. Lime, of course, is needed, but lime should not be considered as a fertilizer. It is largely a corrective of sourness and a mellowing agent.

Planting Trees in Blasted Beds

Shovel out about a bushel of dirt at the point where the tree is to stand. Then with the shovel probe and pry down in the bottom of the hole to see if there is any cavity or pot hole left by the blast. If there is a cavity, pack it full. If the shovel goes in too easily, work it about to compact the ground. Better get in the hole with your feet and tramp the ground a little. If you do not settle the loosened ground in this way, the tree will settle considerably after planting. In case your trees do settle, it is not the fault of the blasting, but of careless planting. The bottom of the hole should be 6 inches lower than is proper for the roots.

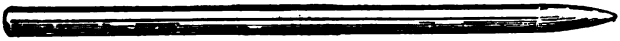
Stand the tree in place 6 inches too deep and sprinkle in some fine, mellow soil. Work this among the roots. You have three means of doing it—tamping among the roots with a stick, working the soil in with your fingers, and shaking the tree up and down. The latter is one of the best means, and should never be neglected. In the process of alternate lifting and pushing down, gradually raise the tree the 6 inches and settle it firmly on a well packed layer of earth at the proper depth, which is determined by the dark line about the trunk, an inch below the surface of the ground.

As the dirt fills up about the roots, pack it very hard. Get in with your feet and tramp it till you think the roots will not have breathing space. You cannot well get it too tight. Sometimes a heavy wooden maul or a broad-faced iron sledge is handy for packing the ground about the roots.

The top 3 inches of ground should not be packed. In fact, it is well to go over the planting four days to a week after it is done, with a garden rake, and loosen any crust that has been formed on the ground about the trees by the drying of rain or dew-soaked surface soil. This will prevent waste of soil moisture. At the same time glance along the rows to make sure of the final line-up of the trees.

When the blasting is done in the summer or fall, and the trees are to be planted the following spring, some lime may be sprinkled over the ground with good effect. It is even better to shovel out the loose earth and sprinkle some lime in the bottom of the holes. The lime will help to make the soil more mellow.

Orchard trees should be pruned soon after planting. If they are left with high, heavy tops the wind will work the roots loose in their new beds before they have had a chance to take hold. By cutting back the limbs properly the wind is given less chance at the trunks.



Steel bar for making holes.

Soil auger—note long point.

Preparing Charges of Explosives for Firing

What a Charge is

A charge of explosives for the purposes of these directions is considered to be all the explosives needed for a single hole with cap and fuse or electric blasting cap properly inserted in the cartridge of dynamite (see pages 143 to 150) and tamped in the hole, ready to fire. The preparation of charges is practically the same for all sorts of farm blasting. The slight variations advisable to suit different kinds of work are not enough to call for separate treatment, since the principles are all the same.

All who use and buy explosives should read the next chapter, beginning on page 152, on the nature and actions of explosives. It is only the man who understands all the facts mentioned there who will be able to load and blast with greatest ease, speed and results.

Scope of This Chapter

It is important for everyone who blasts to understand why he does things, as well as how to do them. For that reason the following discussion of the preparation of charges is made full and complete, with due attention to all the important factors involved. Details of any particular part of the operation can be found quickly by referring to the heading desired, as given in the index.

Readers who may not desire a full discussion are referred to the following brief outline of the process.

Be careful that explosives, cap and fuse are in perfect condition. Cut a length of fuse sufficient for the hole to be loaded, making the cut clean, without dragging ends, at right angles.

Pick a cap from the little tin cap box, carefully, with your fingers, and slide it gently on the end of the fuse. With a proper cap crimper fasten the cap securely to the fuse, making the crimp close to the open end of cap. Avoid twisting or punching the end of fuse against the bottom of cap as well as drawing it away from the bottom. For wet work waterproof the joint of cap and fuse with tallow, soap or other material. Do not use thin grease or oil.

Next punch a hole at a long slant in the side of the dynamite cartridge to be primed. Better use a wooden punch for the purpose. The handle of the cap crimper may be used.

Insert the cap in the hole made as described, tie the fuse in place, and, for wet work, waterproof all openings in the cartridge. You then are ready to load.

Provide space enough in the hole at the proper point to hold the required amount of explosives in a bulk that is not too long. Be sure before you start to press in the cartridges to the bottom of the hole (see pages 135, 148) that there is enough clearance to permit their easy and certain entrance. Tamp fully and firmly up to the top of the hole.

The charge is now ready to fire, which may be done by pressing the burning or flaring head of a freshly scratched match against the powder in the split end of the fuse.

Carrying Explosives and Supplies

Protection of Explosives

The place to keep the explosives is in the magazine or storage place, and not with you in the field. Carry with you in warm weather only enough for the job or the day, or in cold weather only as much as can be kept warm and in condition for firing until you are through loading. Keep explosives separate from caps.

A good way to carry the caps, fuse and small tools is in a basket. Put a piece of blanket in the bottom, to keep

out dampness when the basket is on the ground. Some blasters use an explosives box for the purpose, putting a wood handle or double wire bale on it. The tight wood box probably is a little better than the basket because it affords somewhat more complete protection to the contents.

Whatever the method of carrying the explosives, it should be well protected. This consists in keeping the hot sun off it, keeping rain and fog off it, keeping it away from dampness of the ground, and keeping it safe from meddlesome people and animals.

Many blasters prepare charges before going to the field, but it is better practice to carry along the tools and materials, and to put them together or make the primers on the spot after all the holes are made in the ground or rock, and when everything is ready for the firing except to put the explosive in place.

These remarks are given as reminders. Full discussion of proper handling and storing of explosives can be found on pages 167 to 169 respectively.

Tools and Materials Required

The first step in preparation of charges is to assemble the following: as many cartridges of explosive as will be required; a sufficient number of blasting caps; a sufficient quantity of fuse; some string; a wood punch with an end the size of a cap for about 3 inches; a pair of cap crimpers; a pocketknife. If the holes are very damp or full of water you also will need some tallow or other waterproofing material.

A handy box for carrying supplies to field.

Putting Caps and Fuse Together (Making Primers)

Fuse is described as to sizes and properties on page 166 and caps on pages 165 to 166. Readers who are not familiar with them should turn to those pages at this point. Unroll the fuse and cut off a length that will be enough, since fuse burns about 2 feet in a minute (there are variations—see page 167).

The Fuse

Three feet will give you 1½ minutes or a sufficient time to get beyond danger under ordinary conditions. The fuse, of course, must be long enough to reach out of the mouth of the hole when the charge is in place. Measure the depth of the hole before you cut the fuse.

Warm cold fuse before attempting to bend it. It may be taken into any warm room for the purpose but should be subjected to no heat greater than 110 degrees. If for any reason you have doubts about the condition of your fuse, cut off a foot or more and try it without any cap or explosive. If it will burn properly it is all right.

Be sure to get fresh ends both for the match and to put into the cap. If fuse has been cut for some time into lengths, it is well to cut off short pieces from the old ends in order to bring fresh powder right to the tips.

Cut the fuse off squarely across as shown in the diagram.

Cutting the Fuse

The end of the fuse where cut off should be clean and free from dragging ends and threads. If it is not cut off clean, part of the covering may double over the end of the fuse in the cap and keep the spark away from the explosive, causing a misfire. Be careful to keep both ends of fuse off damp ground and out of puddles of water.

If the fuse has been mashed, or is too thick to go into the cap easily, do not peel off any of the covering. Reduce the diameter by squeezing it with the cap crimpers or by rolling it on a smooth surface under a knife blade or other smooth implement. Sometimes you can reduce it by rolling it between the thumb and finger.

The very best way to cut fuse is with a combined fuse cutter and cap crimper or on a block of wood with a sharp knife. The blade can be pressed right through the fuse and will make a clean cut. Be careful to avoid twisting, pinching or otherwise knocking the freshly cut end of the fuse about, for you may shake out the powder back far enough to cause a misfire. The powder should come out flush with end.

To get one cap out of the tin box in which they came, tilt the box up on edge till some of the caps slide forward, and then pick the cap up with your fingers. Don't attempt, on penalty of losing a hand, to take a cap out of a box by running a nail or a little stick or the fuse into it in the box. Be careful you do not drop a cap to the ground or floor.

The Cap

Turn the cap upside down, to make sure there is no dirt in it, and gently slide it on the fuse till the end of the fuse just touches the bottom of the cap. Do not ram, press or twist the end against the bottom.

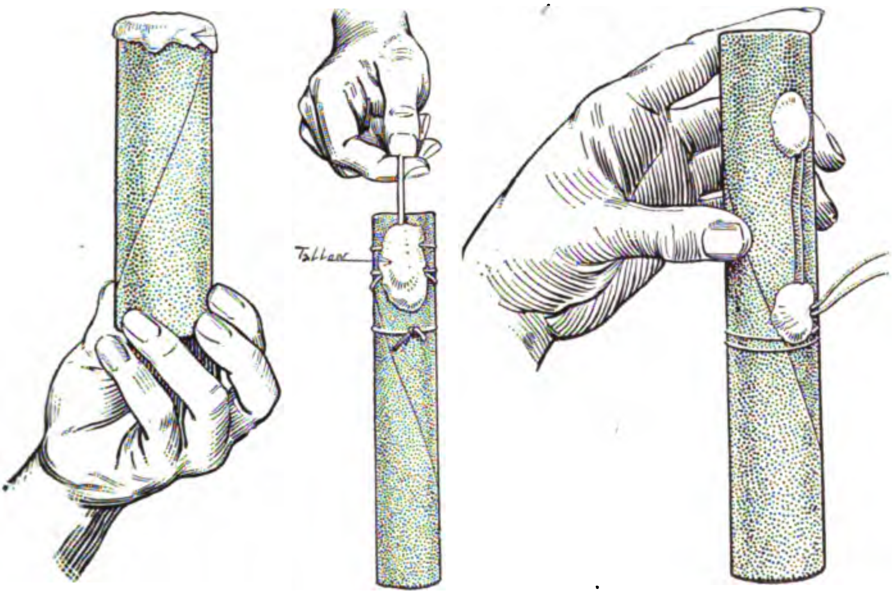
Crimping

Hold the fuse with capped end up, to keep the cap from sliding off, and crimp the cap fast. This you do with the special plier like tool called a cap crimper. The "crimp" is made by pinching the open end of the cap tight to the fuse. It should be made within the last quarter inch of the open end of the cap. Never make it toward the closed end because you might disturb the explosive material in the bottom of the cap and cause it to explode.

"Crimp" or fasten caps to fuse with a regular crimping tool. This tool does the job far better than it can be done in any other way.

Cap crimpers are supplied by all makers of explosives. Order one or more when you buy your explosive. It is well to have an extra one about to use in case you lose one on extensive jobs.

This fastening of the fuse to the cap is one of the points in blasting where a great deal of abuse occurs. Blasters think they can take a chance with danger or with misfires, and attempt to crimp the caps some other way. Except in extreme emergency don't try to crimp a cap with anything except a regular crimping tool; but there are times when one may not have a crimper nor be in a position to wait till one can be purchased. There is a way out of this difficulty—which is to secure a makeshift crimp, with something else than a crimper. It is possible to use a pair of pliers, or a small pair of pincers, and accomplish something that may hold the cap on the fuse. The best makeshift crimp is to take a fold of the cap up at one side of the mouth with a pair of close fitting, square-nosed pliers. Be careful while doing this that you do not grind the end of fuse against the bottom of cap, or pull the end back from the bottom. If the fuse should pull away from the bottom of cap a quarter inch, a misfire likely would result.



Waterproofed (tallowed) cartridges ready for loading in wet holes.

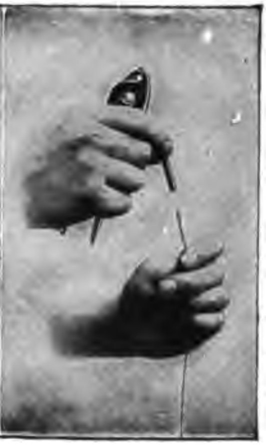
Waterproofing When the charge is to be placed in a dry hole, waterproofing is not needed, but in a wet hole the connections between fuse and cap must be made water-tight with tallow or soap. Do not use grease, because it may unite with the tar in the composition of the fuse cover and soften it, when the powder train will be ruined. Water in the cap will surely make it worthless.

Inserting Caps in Explosive

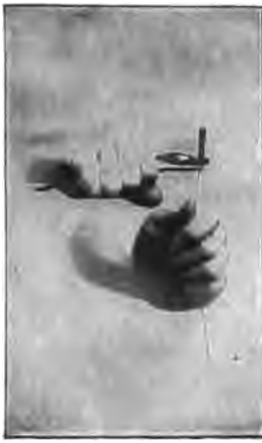
The best location for a cap in a cartridge of explosive for farm blasting is in a hole in the side, about an inch and a half from one end. The best position for the cap at this point is at a slant that takes it in from the side toward the center, but as near longways, or parallel with the sides of the cartridge, as possible.

In cutting fuse from roll use sharp knife.

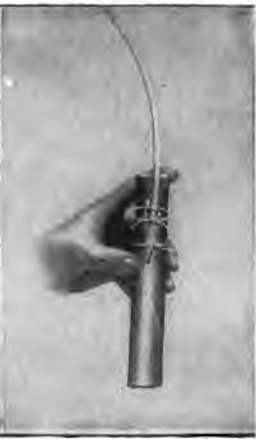
Taking one cap carefully from box.



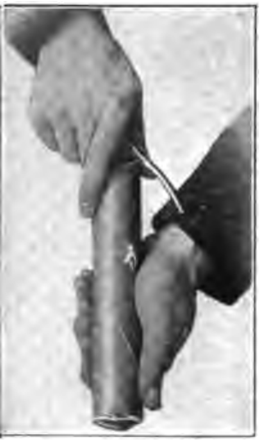
Inserting fresh end of fuse in cap.



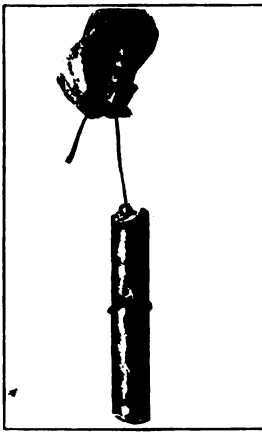
Crimping cap with the cap crimper.



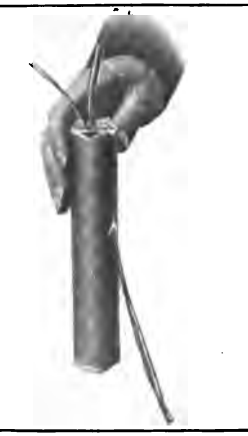
Fuse tied firmly to cartridge with string.



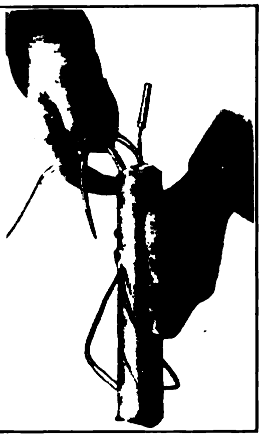
Electric Blasting—Pass the doubled fuse wires through a hole in cartridge.



Loop the doubled end of fuse wires over end of cartridge.



Pull loop tight, bend wires at cap, punch hole in top of cartridge.



Insert cap in hole, take up slack in wires. (Waterproof holes if ground is wet.)

Position of Cap in Cartridge

In other words, when making the hole for the cap in the explosive, make it with as long a slant down toward the other end of the cartridge as possible. There are reasons for this connected with superior or inferior detonation.

Another method of priming much used is to insert the cap in a hole made in the end of the cartridge of explosive, and then to tie the paper about the fuse or wires. This is good so long as it is not damaged, but care must be exercised not to have the tamping stick interfere with fuse or cap. With side priming there is a cushion of the soft explosive between the end of the cartridge and cap. End priming always is good provided sufficient care is taken in loading to prevent disturbing or displacing the fuse or cap with tamping rod.

When all the explosive is removed from its wrapper, the cap must be inserted in the loose explosive. This should be done by making a hole, as in a cartridge. But it seldom pays to take all the explosive out of its wrapper. Nearly always you can leave a half cartridge of explosive intact for the cap.

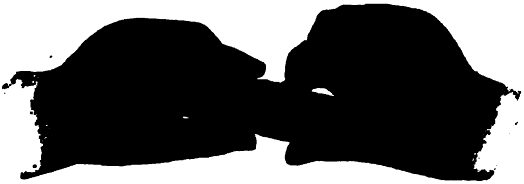
A good crimp.

Making Hole in Explosive

To make the hole for the cap use the handle of the cap crimper or a wooden punch just a little larger than the cap. The hole should be large enough to let the cap in without much pressing, but should leave no air space about the cap. The depth of the hole also is important. It should be just enough so that the entire cap can be buried in the explosive, but not any deeper. If it is deeper, the cap may be forced on down to the bottom, which will leave some of the fuse in contact with the explosive (which may cause burning instead of exploding of powder), or the cap may be seated just inside the wrapping, leaving an air space at the inside end or bottom of the hole, which may lower the effectiveness of the explosive.

Fastening Fuse to Explosive

When the cap is seated in its hole in the side of the cartridge, the fuse will extend up along the cartridge past the near end. It must be tied in this position, so securely that the fuse and the cap will not be pulled back in handling or by rubbing against the side of the hole when the cartridge is pressed down. The best way to secure it is to wrap a strong string several times below the point where the cap is inserted, then give two or three wraps about the fuse, and pull tight and tie; or take two loops about the fuse and then several wraps about the cartridge.



Cutting cartridge in two—roll it under knife blade.

When the foregoing directions have been complied with you have a cartridge of explosive primed with a cap and fuse. It is ready to put in the bore-hole in the rock or ground.

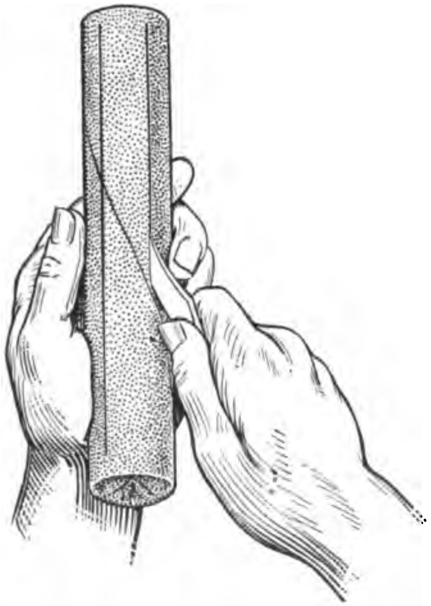
Loading Charges in Holes

Tamping Rod

You will need a tamping stick. This must be of wood, and had better be about the size of a cartridge of explosive, which usually will be 1¼ inches in diameter, except in case of blockhole blasting of boulders, when a smaller cartridge sometimes is needed to go in small drill holes. Never use a metal rod for tamping. Make sure that the hole is ready. It must be big enough to allow cartridges to slide down easily (except in the case of small holes drilled in rock, when the explosive all must be taken out of the wrapping and crumbled and pressed into the hole). Loose stones, sharp stones and roots that obstruct the hole should be removed with a bar or spoon scraper. This work must be completed before starting to load. If obstructions fall into the hole, after some of the explosive is in place, don't try to remove it by force. Make another hole at a safe distance from the first, put in another charge and fire it.

Measure the hole with your tamping stick and judge if there is space for the required charge at the right point. Nearly always a charge of explosives should be as compact as possible. If one or 2 cartridges are all the explosive required, it usually will not hurt to put them end to end. But if 3 or more cartridges are required, to put them end to end makes the charge too long, and places the force of the blast elsewhere than where it should be.

The tamping rod should be of wood.



Slitting the paper wrapping of cartridge to let it swell to fill dry holes.

When your judgment tells you that the charge should be in a more or less round bulk, enlarge the hole at the point where the charge should be made. Sometimes this can be done by scraping it out at the bottom with a toe-bar or spoon-bar. Again, if much enlarging is required, it is well to use a small amount of explosive to secure it. This is called springing. To do this prime about a quarter of a cartridge as usual, and push it to the bottom of the hole. Use no tamping. After it is fired wait till the hole cools, and you will find a cavity large enough for your full charge.

It is better to avoid springing holes if you can, on account of the fact that the cavity often is enlarged too much, and the surrounding earth is loosened so much as to injure confinement. (See page 156 on detonation). A great deal can be done by scraping the small auger hole out to 2 or 3 inches in diameter at the bottom and then causing the

cartridges to enlarge and fill the hole solidly. To accomplish this enlargement of cartridges, slit their wrappings 3 or 4 places lengthwise, from end to end. Then press them home with the tamping stick. They will expand and shorten. Four to six cartridges in this way can be got into the full length of two.

Still another way is to take the explosive entirely out of the cartridge wrappings, and with the help of a tin or paper tube, such, for instance, as calendars are mailed, funnel it down to the bottom of the hole. But neither this method nor slitting the cartridges is wise in wet holes. It is true that nitroglycerin powders will stand considerable water, but the safe rule in wet blasting is to leave the cartridges intact. Ammonia dynamites will not stand wetting inside the paper of the cartridges without damage. (Never under any circumstances cut, break, unwrap or punch holes in explosive that is frozen. You invite an explosion in your hands when you do.)

When there is more than one cartridge in the charge, place the primed cartridge on top of the others—put it in the hole last or next to last—when using the cap-and-fuse method of firing.

Be sure that all parts of the charge are in firm contact. It will not do to have air spaces, or dirt, or wrinkled paper between the cartridges. While all the powder likely would go off under these conditions, it will not do as much work as it should.

The cartridges of explosive may fit tightly in the holes. In that case do not ram or pound them, but press firmly against them, one at a time, with the tamping stick. Press the explosive into tight contact with the sides all round, at the bottom of the hole.

Tamping

Tamping is a necessity and one of the most important parts of the operation. The charge should be tightly confined. It is only in springing holes and sometimes in digging post holes that no tamping is advisable, and in ditching that the quantity needed is less.

Tamping

When the explosive is in place at the bottom of the hole, start the tamping by rolling in some loose ground. Keep the tamping stick working up and down to seat this ground against the explosive, though make no effort to get it tight till there is a few inches or so over the explosive. An exception to this rule is in the case of blockhole blasting of boulders and ledges, when damp clay tamping should be packed solid all the way down to the explosives.

If the tamping is less than this, the best results will not be secured, hence deep holes often are necessary for the sake of confinement of charge as well as to contain the amount of powder used.

Hold the fuse to one side with one hand while the tamping stick is worked with the other hand. Rake the dirt to the mouth of the hole and be careful to get in the hole only earth—not clods, sticks, grass, etc. Be very careful not to damage the cover of the fuse with the tamping stick.

Fill the hole to the top with tamping, and make it tight. The best material for tamping is moist clay. Tamping material always is better when made *wet* enough to ball. Use the heaviest earth within reach, and if it is dry, moisten it.

Firing

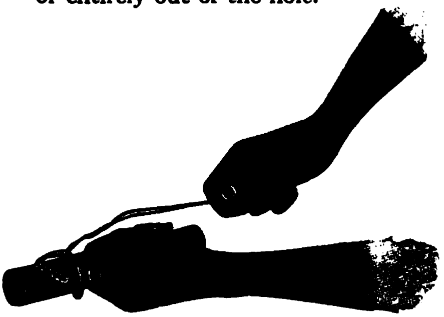
The free end of the fuse will stick out of the hole filled with tamping, say about 4 inches. Your remaining work is to set fire to the powder in the fuse, till it begins to spit continuously. Split the end of fuse with your pocket knife to make it light easily. Put the flaring head of a freshly scratched match against the powder exposed by the cut. (See page 159.)

Preparing Charges for Electric Firing (Making Primers)

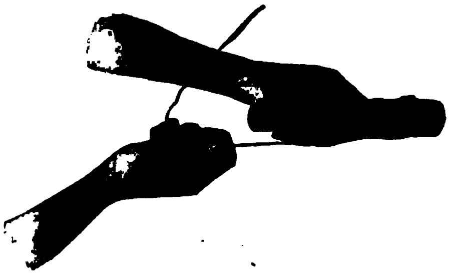
Up to this point in the directions for preparing charges the text has spoken only of caps and fuse. When the firing is to be done with an electric blasting machine instead of fuse, you must use electric blasting caps.

These come from the makers with the wires already fastened in them. (See pages 165 and 166.) They are ready to be inserted in the cartridge of explosive without any preparation such as ordinary caps and fuse require.

Make a slanting hole in the cartridge of explosive just as is described on pages 145 to 147. Into this insert the electric blasting cap, letting its wires project just as the fuse does when fuse is used. Then tie the wires to the cartridge with a string as fuse is tied, to prevent the cap from being pulled partly or entirely out of the hole.



Bad method of fastening wires. It is better to tie them.



Bad position of cap in cartridge, and of cap wires.

It is a little difficult to tie the wires tight enough with a string to prevent slipping. Another way to fasten them securely is to punch a hole from the center of the end of the cartridge in a slanting direction so that it will come out at the side two or three inches from the end. Bend back the electric blasting cap wires about eight inches from the cap and insert the loops of the doubled-over wires in the hole in the end of the cartridge, pushing it out through the side. Open out the loop in the wires and pass the loop over the other end of the cartridge. Punch another hole in the end of the cartridge a trifle to one side of the first hole and straight down toward the center of the cartridge. Insert the electric blasting cap in this hole and then take up all slack in the wires. The result will be a primed cartridge where the wires do not cross each other at any point and the electric blasting cap is lying parallel with the center line of the cartridge. A cartridge so primed hangs vertically so that it is possible to load it in a vertical bore hole without its lodging against the sides. See page 146.

In fixing wires of electric blasting caps to cartridges, avoid crossing them and avoid bending them sharply or in any manner that will break their insulation. If the insulation is broken it likely will cause a short circuit, which will result in a misfire. *Never take a half hitch about the cartridge with the wires.* Do not pull at the wires and the cap, because to do so may break the fine bridge wire that causes the cap to explode when the current goes through.

Load these primed cartridges the same as is directed for fuse primed charges. Be careful to avoid rupturing the insulation on the wires with small stones in the hole or with the tamping rod.

The finishing of the tamping leaves two wires projecting from each hole. They must be connected with the blasting machine or other source of current with connecting wire and leading wire, in the manner described fully on pages 161 to 164. Further discussion is not needed at this point.

Some General Suggestions

In priming cartridges of explosive with fuse and blasting cap, you must be careful to avoid permitting the fuse to touch the explosive. High explosives will burn like gasoline or coal-oil. They are very easily set on fire by sparks spitting from fuse. When they are burning the explosion will be very much weaker than it otherwise would be, and will give off noxious gases.

A very frequent cause of misfires is the bending, kinking and crooking of fuse. This is especially frequent when the cap is inserted in the center of the end of the cartridge of explosive and then carelessly forced over against the side of the hole by the tamping stick and tamping material. Keep the fuse straight, and never under any circumstances lace it through the cartridge of explosive. That is a sure cause of trouble.

If it becomes necessary to remove a cap from a primed cartridge of explosive, do it gently and carefully, and unless the cap and fuse are immediately to be inserted in another cartridge, destroy them both by lifting a shovelful of earth and putting the cap under the ground in the hole, after which light the fuse and go away.

It is better not to lift or carry the primed cartridge of explosive by the fuse or wires when it can be helped. When a practice of carrying primed cartridges by the fuse is made, misfires and poor explosions will be caused, not every time, but often enough to make it wiser not to do so. The cap often is pulled back in spite of the tie string.

Where explosives that are subject to water damage are used in work that is wet, matters can be helped by making the cartridges waterproof with tallow, paraffine or other suitable material. It is practicable to stop all the seams on the cartridges, load and fire without delay, even with explosives that would be put out of business if the water got at the actual material instead of only at the wrappings of the cartridges. Pay particular attention to waxing or tallowing the place where the cap and wires enter the cartridge.

When doing wet blasting, use every care to keep the outer end of the fuse from dropping into the water or from resting on damp ground. The inner wrappings of fuse and the powder train itself take up water like a blotter. On a very foggy day it is well to keep fuse in a closed box. Mist and rain, of course, will damage it.

Explosives and Blasting Supplies

The catalogs of manufacturers are not intended to give all the fundamental facts about and the differences between the various explosives. To do so would take too much space. They give the trade names and the measurements and weights of cartridges and boxes, demanded by purchasers, and are prepared on the supposition that blasters and buyers of explosives know what they need. This bulletin includes explanations of the names under which blasting explosives are made and marketed, outlines their properties, and makes clear the work and conditions for which each grade is intended and suited.

Explosives

Names

There are scores of different kinds of explosives made and used for blasting purposes, and many dozens of different names used for them. The most familiar name of any explosive in America is dynamite. Other names are farm dynamite, quarry powder, contractor's powder, coal powder, stumping powder, Judson powder, gelatin, blasting gelatin, R. R. P., giant powder, blasting powder and dozens of others.

Nearly every one of the explosives designated by these names is made in several strengths, and in qualities to suit varying conditions. For this reason figures and other marks are attached to the names to distinguish the grades. In addition to this some of the names are used to designate not only one certain explosive but several widely different ones. This is particularly true of the names dynamite and powder. The selection of names in the preceding paragraph is made for illustrative purposes, and is not to be taken in any sense as a recommendation of those explosives for any purpose. The recommendations are given in detail on other pages.

Differences

All blasting explosives are not made from the same ingredients, and they differ a great deal in many other ways than in quality, as quality is generally understood. You can buy cornmeal that is good, bad or indifferent, but when you buy explosives you will find there are few which can be classed as of poor quality. Nearly every standard kind and grade is of excellent quality for some particular purpose and condition. And practically every one can be classed as of poor quality for conditions and purposes to which it is not suited.

Nor is the difference one of size of cartridge or grain, as the case may be, though this is one element. The main differences are ones of strength, quickness or speed of gases, sensitiveness, resistance to cold and to water, density, fumes and cost. Some explosives are suitable for wet work, and others only for dry work; some are adapted to blasting hard, tough rock, others to blasting ground only; some freeze when chilled a little; others can be exposed freely without freezing. And it should be noted that many of the better explosives of to-day have been developed during recent years and are comparatively new. The explosive to buy for any particular work is the best one on the market for all the conditions involved.

Explosive Ingredients

Black blasting powder has been known and used for several hundred years, and it is practically the same to-day as it has been for a long time. It is composed of saltpeter or nitrate of soda, sulphur and charcoal. It does not vary in strength, and varies little in other properties.

The dynamites and high explosive powders have little or no relation to black blasting powder. They depend for their explosive force on other explosive chemicals the best known of

which are nitroglycerin and ammonium nitrate. It is not necessary in this brief description to name additional explosive elements.

The first dynamite was made in Europe by mixing nitroglycerin with a light spongy earth, and packing the mixture in paper tubes as cartridges of dynamite and powder are packed to-day. Nitroglycerin itself is a wonderfully efficient explosive when it can be controlled, but it is so sensitive to shock that it must be mixed with absorbents and treated to make it safe enough to handle.

As other explosive chemicals become better understood, it has been found of advantage to substitute materials that are explosive for the light earth used to absorb the nitroglycerin. And more than that, the nitroglycerin itself has been displaced to varying degrees in some of the dynamites by ammonium nitrate and other materials. Few blasting explosives contain no nitroglycerin at all, but many contain only 4 or 5 per cent. of it. Each of these combinations of materials, or formula, has its own peculiarities in addition to variation in strength, all of which information it is well for a buyer and blaster to understand.

The explosives marketed as "straight dynamites" are made from nitroglycerin. Those made from an ammonium nitrate base are called by many manufacturers "extra" dynamites. Gelatin dynamites and blasting gelatin are nitroglycerin explosives in which the nitroglycerin has been combined with gun cotton. The various special mine, quarry, stumping, farm and other miscellaneous dynamites and high explosives on the market are not so named that their ingredients can be determined without a statement from their makers.

Strength and Quickness

The power of an explosive and its violence are two different qualities. The power, or direct strength, is due to the volume of the gases. If a pound of a certain explosive gives, for instance, 1,000 cubic feet of gas when completely detonated or fired, while a pound of another explosive gives 500 cubic feet and a pound of a third gives 2,000, the lifting power of each explosive will be in direct proportion to its gas volume.

But the violence of the gases depend, not on their volume, but on their speed. If they are comparatively slow in forming and in forcing their way out of their confinement they will break out large cracks and escape through them, pushing the material aside. If they are very fast or quick, they will grind and pulverize everything they come in contact with, and throw out the whole side of the confining material, but will not crack it so far.

The matter can be made clear by comparing a push with a blow of a hammer. Both may have equal power, but the effects on a block of wood, for instance, at the point where they are applied are very different. The push will move the object almost without marking it. The blow may move it, but it is sure to leave a mark of greater or less depth, depending on the nature of the hammer and its speed. A still better comparison, perhaps, is that between the blow of a sledge and of light hammer. It is possible to hit a blow of as much power or weight with one as with the other, but the material at the point where the blow lands with the light hammer will be badly dented, or maybe broken. The reason is that the light hammer moves with much greater speed.

In quarries blasters make use of these facts in order to get the rock broken out in pieces of the size preferred. When they want large pieces they use an explosive with sufficient power to break the rock, but, comparatively speaking with a slow speed of gases; when they want small pieces and much shattering, they use an explosive of the same or greater power but with swift and violent gas action.

For each result and for each material a certain power is required and a certain quickness of the gases is best. By way of illustration, take soil blasting for tillage purposes. There is no object in violently grinding the earth at one spot while surrounding earth that might be reached is left untouched. A proper explosive for this purpose is one that will have enough pulverizing action, that will lift and shake up the soil, and that extends its effects for long distances. For an example of the other extreme, take mud-capping rocks. For this work the explosive cannot be too violent in action. The gases, backed up by the rapidly yielding wall of air behind them, must strike the rock a crushing blow in the minimum of time.

Nitroglycerin and ammonia dynamites, for all practical purposes, are of equal strengths when of equal markings. The strength is indicated accurately by percentage figures.

Nitroglycerin explosives are uniformly quicker and more violent in action than ammonium nitrate explosives, and the more nitroglycerin there is in the explosive the quicker it is. The ammonia explosives are not as quick, in any strength, as the corresponding nitroglycerin explosives. Therefore a 50% nitroglycerin dynamite is more violent than a 50% ammonia dynamite, and a 20% ammonia dynamite is much less violent than a 50% grade.

When the object is to shatter and reduce to fine fragments the material to be blasted, the proper explosive is a quick one, while when the object is to lift and shake up the material the best explosive is a slow one. (See table on page 156, also detailed recommendations on pages 136, 152 and 156.) But there are other factors that must be considered.

Nitroglycerin explosives resist water better than ammonia explosives, but if the cartridge wrappings are not broken or opened, ammonia dynamite or powder can be loaded in wet holes with entire satisfaction. The firing should not be delayed any longer after loading than necessary, and it is wise to plan the work so that it may be done at the longest within a half hour after loading. Storage in a damp place will weaken explosives, especially ammonia explosives.

Gelatin explosives resist water very well, and may be loaded in wet holes, or under water, with assurance that they will explode with their full power. Blasting gelatin is entirely water-resisting.

Explosives will freeze, and when in this condition are dangerous, and cannot be fired properly, if at all, with a cap of any kind. They *must* be thawed and they must be handled very carefully if they are to be used. On no account attempt to cut the wrappings, to break a cartridge or to handle the frozen explosive in the ordinary way. (See pages 157 to 159 for directions for thawing.)

Freezing

Regular nitroglycerin explosives are quickest to freeze. Others, known as "Low Freezing," will stand much lower temperatures without causing trouble in this respect.

Ammonium nitrate explosives also will freeze, but not quite so quickly as nitroglycerin explosives. They too are made on both regular and low freezing formulas. The low freezing ammonia will stand more cold than the low freezing nitroglycerin.

The regular explosives will freeze at temperatures of 45 to 50 degrees. The low freezing explosives will not freeze and become solid till the thermometer gets down below the freezing point of water, and in practice many of them can be used right out in the open when the temperature is down to 32° F. for some time before starting to freeze. The length of time the powder is exposed to the cold has much to do with its freezing.

The safety point for both low-freezing explosives and regular explosives is not a matter of rule, but of watching the explosive. When dynamite is frozen, the cartridges will be hard, and when it is partly frozen they may have a mottled appearance on outside of the paper wrappings. The hardness may only be in spots. When not frozen, the cartridges should be a little soft all over. No explosives should be handled much, cut, punched, rubbed, broken or loaded when they are frozen. They cannot be exploded satisfactorily and such acts are dangerous.

In cold weather always use the low freezing grade of explosives, for the regular grades may freeze in the holes before they can be fired. It is a good plan to use the stronger caps, say No. 8 (see page 165) in cold weather. When a charge of explosive is chilled but not frozen it can be fired satisfactorily by a heavier impulse (blow and heat) than ordinary, such as a fresh No. 8 cap gives. The low freezing explosives do not differ in action from the regular explosives, and are just as efficient.

The gases of explosives naturally are more or less objectionable when breathed. Some of them are poisonous, others are merely disagreeable. When explosives are used out in the open the gases are taken up by the air so quickly that none of them give any serious trouble, though they do cause headaches if the fumes are inhaled. It is only in tunnels and deep shafts where the air is confined that the matter of fumes is important, not on farms.

Other Properties

Special explosives have been developed for tunnel and mine work, but they are not important in agricultural work. The only fact about fumes worth knowing in farm blasting is that nitroglycerin explosives either in the form of their gases or when absorbed through the skin will cause headache somewhat quicker than ammonia explosives. The so-called fumeless explosives always cost more than any ordinary dynamites and are not suited to farm work. Farmers will do well to buy grades of explosives suited for their special purpose.

Appearance of Explosives

Most dynamite is a light-colored material that looks like fine, sticky sawdust, and it is packed in "sticks" or cartridges made with cylinders of tough paper. These cartridges vary in diameter and length. The standard is 1¼ inches in diameter and 8 inches long. This is the size carried in stock by dealers and in the magazines of the makers. Sizes other than the standard 1¼ by 8 inch may cost more per pound than the standard owing to higher packing cost.

Dynamite is usually packed in wooden boxes containing 25 pounds or 50 pounds. A 50-pound box of 20% ammonia dynamite will contain about 100 1¼ by 8-inch cartridges. If of 20% nitroglycerin, it will contain about 98 cartridges. If of gelatin dynamite, it will contain about 88 cartridges.

A word should be said here about the cost of explosives. No quotations can be given because the prices vary in different parts of the country and from time to time. The ammonia products usually are cheapest. The cost of course follows the percentage strength, the low percentages cheaper and the high percentages dearer. Gelatin explosives cost about the same as straight nitroglycerin explosives. The special explosives for use in mines, tunnels, quarries, railroad construction work, etc., often cost more than the explosives recommended here for farm work.

In buying explosives look first to getting the one that is best suited to the work to be done, and aside from that the cheapest one. There would be no object in using a straight nitroglycerin or a gelatin explosive when one of the ammonia farm powders would do the work, for the former explosives cost much more than the latter.

To avoid "explosive misfits" it is well to consider carefully the nature of the material to be blasted, the conditions of weather, water, etc., and the results wanted. The kind of explosives to use depends on these factors. Keeping in mind the facts mentioned in preceding paragraphs, the reader will see that there is a type of explosive made for almost every condition and kind of work, and will understand why one will not suit the work of another.

As the briefest and clearest way of giving general suggestions for the type of explosive best for different agricultural work, a table follows: (Detailed recommendations are given on pages 136 and 152.)

Explosives Recommended for Different Work

Stone blasting—mudcap	Straight nitroglycerin or ammonia dynamite, 50% or 60%.
Stone blasting—undermine "Snake holing"	To break, same as for mudcapping; to throw out, use any dynamite of 20% strength.
Stone blasting—blockhole	To shatter well, any high percentage dynamite; to break into large pieces, 20% ammonia dynamite.
Soil blasting—for subsoiling and for tree planting	20% ammonia dynamite.
Ditching—electric firing	20% to 40% ammonia explosives; (nitroglycerin is equally effective); in loose dry ground, high percentage nitroglycerin explosives.
Ditching—transmitted detonation	Straight nitroglycerin dynamite, 50% or 60% strength.
Stump blasting—in medium and heavy soils, wet or dry	20% or 30% nitroglycerin or ammonia dynamite.
Stump blasting—in dry sand and other light soil	40% or 50% nitroglycerin or ammonia dynamite.

If you are in doubt as to the best explosives for your particular work it is well to write to the manufacturer you prefer, asking which of his grades and brands would be most suitable.

Detonation

It is well known that black powder is fired by a spark, and that dynamites and high explosives cannot be fired by a spark but require a combination of shock and heat such as is produced by a detonator. It is not so well known that there are great differences in the nature and effect of the explosion of any dynamite, due to variations in the way it is fired.

Firing, Exploding or Detonating

An explosion of dynamite is the result of a very sudden creation of a great volume of gas from a smaller volume of explosive. The kind and amount of gases produced by any high explosives depend on the kind and amount of shock used to fire the charge, and on its confinement.

The effect of lighting a piece of unconfined dynamite with a piece of fuse without a cap on, is that the dynamite will burn fast without exploding and make a dense smoke which has a bad smell and produces severe headaches. This is simple combustion. If the piece of dynamite is confined closely and lighted in the same way it will explode, but will give off similar bad fumes. If a weak cap is used on the fuse, or the dynamite is set off by a fall, the dynamite will be partially detonated, and explode with considerable force, but it still will give off the bad fumes and smoke. The same piece of dynamite fired with a No. 6 or 8 cap will be completely detonated, and will explode with great violence and force, even when unconfined, except by air, and will give off very little smoke.

The last-named explosion is detonation. It is produced by a violent shock in connection with intense heat. Nitroglycerin is 5 times as strong as black blasting powder when exploded by fire, and 10 times as strong when detonated. This explains the enormous force given by detonation as compared to simple explosion.

But detonation itself is no set thing that always takes place the same. There is good, or complete, or full detonation, and there is partial detonation. In case of incomplete detonation, or any detonation at a less speed than the greatest for any particular explosive, the gases formed are not what they should be. For one thing, they are more noxious or poisonous. The more powerful and severe the blow delivered by the cap, the more quickly does the chemical action take place in the explosive. It is only when high explosives detonate with their greatest speed that their maximum power is generated.

Air spaces about the cap in the cartridge of explosive cushion its blow and weaken detonation. It is the nature of the initial detonation of the powder right around the cap which governs the nature of the explosion of the whole charge. A blaster should understand the importance of setting up *complete* detonation in order to get the greatest amount of force out of explosives. Sometimes explosives lose as much as 20% of their effectiveness when fired with weak caps. Lack of confinement has a similar effect. Sixty per cent. dynamite poorly detonated is less effective than 40% well detonated.

When explosives become chilled it is difficult to detonate them properly with the usual cap, hence the advisability of using a very strong cap in cold weather—a No. 8. Many of the holes are frequently loaded for some time before firing, and even if the powder is soft and normal while charging, it afterwards becomes somewhat chilled in the cold ground.

Cap Means Detonator

Throughout this and other bulletins in this series, the terms caps and electric blasting caps are used in speaking of the exploders used to fire the charges of dynamite, although in the field and among manufacturers the same articles are called by the terms "detonators," or "electric exploders," or "electric blasting caps."

Thawing Explosives

It has been pointed out (on page 154) that regular explosives chill or freeze at temperatures of 45 to 50 degrees. With the increase in the number of low freezing explosives that seldom need thawing, the necessity for doing the thawing on farms is not as frequent as it used to be.

Cartridges of frozen dynamite improperly handled are dangerous materials, and whenever the temperature is near the freezing point for them, the cartridges should be inspected before using to see if they show any of the hardness that indicates chilling. If so, handle them very carefully till they are thawed. Dynamites will be a little soft to the pressure of your thumb when they are not frozen.

Frozen Explosive

Frozen explosives are dangerous because they are very much more easily exploded in the course of ordinary handling. They are more sensitive to friction and to blows of tools. The cartridges may explode when broken in two, when wrappings are cut with a knife, when cap holes are punched with a stick, or when they are shoved into a hole with a tamping stick. At the same time they are so much less sensitive to the direct shock of a detonating cap that they cannot be fired properly with a cap. Therefore the rule must be laid down that frozen cartridges of high explosives never must be cut or ruptured or used until they are thawed.

When nitroglycerin freezes it crystallizes, therefore the nitroglycerin in dynamite tends to separate from its absorbing materials into small crystals. When the dynamite is thawed slowly with cartridges lying on their sides, the nitroglycerin is reabsorbed as fast as it liquefies. But when thawed too fast, the nitroglycerin is liable to run out of the cartridges before it is reabsorbed. Quick thawing will damage explosives a great deal more than they would be damaged by freezing followed by long, gradual thawing.

One type of thawer on the market.

Thawing is a dangerous operation when not done right. It probably is correct to state that more accidents with dynamite have occurred in the course of improper thawing than for all other reasons put together. At the same time proper thawing is entirely safe.

Causes of Accidental Explosions

Two of the most frequent causes of accidents while thawing explosives are in putting the cartridges into water or steam, and putting them on hot stoves or stones. Water, and especially hot water, forces the nitroglycerin out of the cartridges. The free nitroglycerin goes to the bottom, and explodes at the time of the first increase in heat, or first light blow. When cartridges of dynamite are laid on hot material the nitroglycerin also runs from the paper wrappings and drops of it fall to the stone or metal. This almost always causes an explosion. At about 350 F. degrees of heat, which is only a little more than that of boiling water, the nitroglycerin will explode without a shock.

Safe Thawing

Examine your explosives a day or so before you are ready to use them, and if they show that they are frozen, proceed to thaw them in one of the following ways: Use only a *DRY* warmth. Use no temperature higher than is comfortable to the hand, or the limit may be set at 100 or 110 degrees. Use no heat of any kind that cannot be controlled with certainty. If you do this you will be safe.

Every large maker of explosives will supply thawing apparatus that is safe. Sometimes this is a double kettle arranged so that the cartridges of explosives can be placed in the inside vessel, while the outside vessel can be filled with warm water and a blanket can be spread over the top. Other more elaborate thawers consist of a vessel containing watertight tubes just big enough to hold cartridges of explosive, running through a space to be filled with warm water. The catalogs describe these ready-made thawers in detail.

Home-made thawers can be arranged with two buckets, one small enough to hang inside the other. Put the cartridges inside the small one and warm water around the outside, in the big bucket. Another good way is to put a five-gallon can of warm water inside a barrel, or box, and pile the cartridges of explosives in the barrel around the can. The top of the barrel should be covered with a blanket. Or put the water in the barrel and the explosives in a can or bucket. A small closet of course can be used instead of a barrel. A can of warm water can be set inside a magazine to keep the temperature up.

The old-fashioned manure pile method of thawing is reliable and safe. This consists in burying a box somewhat larger than a box of explosives in fresh horse manure, and placing inside it the box of explosives to be thawed. A foot or more of manure must cover the box, and a small pipe or tube should be inserted for ventilation. The manure must be fresh. Allow at least 10 hours to thaw a box of dynamite in this way. Twenty hours is better.

The box of explosives can be taken into any warm place that is dry, but if this is a building you must take your own risk of fire and accident. Watch the box and the cartridges to see if the freezing and thawing causes the cartridges to leak free nitroglycerin. If any of this leaks out of the cartridges and gets on the floor it must be washed up according to directions in paragraphs on storage. (Pages 168 and 169.)

Cartridges on Sides

The cartridges of explosives had better be piled irregularly rather than in tiers, for thawing. They will rise in temperature quicker in this way. They always must lie on their sides rather than stand on end.

Electric and Fuse Firing

The very best way to light fuse is to split the end for an inch or less, and stick the burning head of a freshly scratched match right against the exposed powder at the head of the split. This will light the fuse even in a strong wind.

Fuse and Cap Firing

Where there are very many fuses to light in succession, as in subsoiling, it sometimes is of advantage to use a gasoline or other torch, holding the hot flame under the fuse for an instant. Whatever the method, do not leave till you see the fuse spitting sparks and smoke swiftly and regularly. Further discussion of fuse firing, except as to its adaptations, is not needed.

Electric Firing

Farmers who have only a few stones or stumps to blast, or who are planting a few trees or doing a little subsoiling, will not need any other method of firing than by caps and fuse. Ditch blasting in ground not watersoaked demands electrical firing, while the blasting of large stumps, particularly if green, and in sandy soil, as well as the blasting of large rocks, is made easier, safer and cheaper by electrical firing. For large amounts of almost any blasting except that of tree beds, subsoiling and very small stumps and isolated small boulders, the purchase of an electric blasting machine and the necessary wires is justified by the advantages of the electric methods of firing.

A good reel for leading wire.

Advantages

The primary reason for the superiority of electric firing over fuse firing is that several charges may be exploded at once; the different charges will increase the efficiency of each other. Thus in ditching, you can fire many charges in a row and make a perfect ditch. In stump blasting several small charges very often will take a stump out better than one large charge, and in orchard, and garden subsoiling the simultaneous blasts frequently are of advantage.

Electric firing is more certain when the charges are under water. The danger from misfires due to moisture as well as from some other cause is reduced. Should misfire of the electric blasting cap occur, you are safe in going to the charges as soon as the wire is disconnected from the blasting machine. With a fuse you must wait some hours to be safe. When several charges, as for instance, several boulder blasts are to be fired, you can make one trip to safety do for the lot, instead of having to travel back and forward for each shot. The greater safety of electrical blasting is due to the fact that the time of firing a shot is under the control of the blaster. Finally, the intelligent and careful use of electric firing, with its possibilities of two or more small charges doing the work of one large one, and its other economies, will save considerable explosives.

Electric Machine

All the makers of explosives supply electric blasting machines. The machines are small boxes of wood or metal, containing a small dynamo with a handle that you either push down or twist, depending on the type of machine, to operate and to fire the charges. The machines are made in various sizes and capacities to fire 3, 10, 30, or more charges at once. The 10 charge machine weighs about 15 pounds. Full directions for operating and caring for the machines always accompany them.

Duplex Leading Wire. (Actual size.)

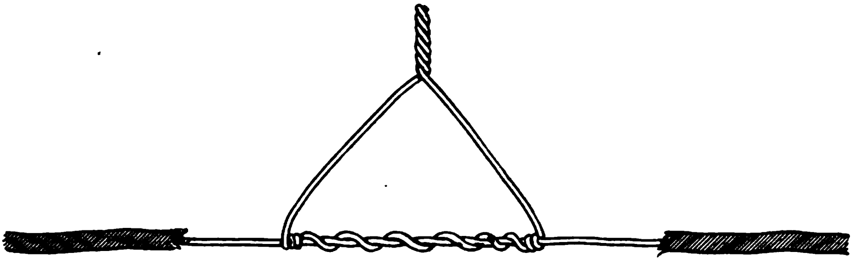
Wiring

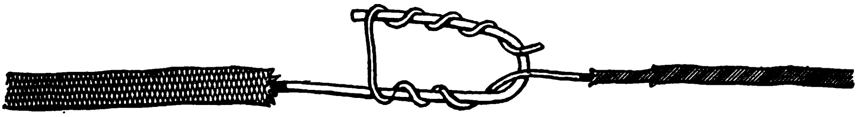
For electric firing, in addition to the machine, you will need electric blasting caps, possibly connecting wire and leading wire. The leading wire is copper wire large enough to carry the amount of current required for the number of charges to be fired simultaneously. It is covered with insulating material, and is made strong and durable to stand much use. To make the circuit from the blasting machine to and through the charges and back again, you must have two strands of leading wire. It comes from the explosive makers in single-strand form, which must be doubled, and in what they call duplex form, which has two strands of insulated wire twisted together or wrapped together under one cover.

Connecting wire comes on spools.

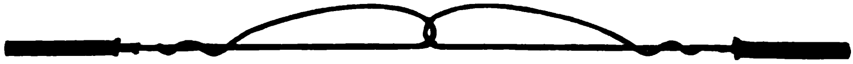
Electric Blasting Caps

The two small copper wires that are fixed in the electric blasting caps (see pages 165 and 166) should be long enough to reach out of the holes. They may be bought in a variety of lengths, but 4 or 6 feet are regarded as standard. If the charges are close enough together so the wires can be connected, no connecting wire will be needed; but whenever the distance between is more, the charges must be connected, and connecting wire is the right thing to do it with. There is no particular limit for the distance between charges that may be connected for firing together.


Good connection for electric cap wires.


Good connection for small cap wires and large leading wire.

Don't Connect This Way

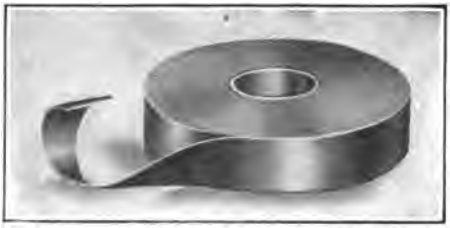

A very bad connection—a cause of misfires.

The diagrams in these pages will show how to make electric wire connections. Cut away the insulation on the wire ends and wrap the ends together tight. Wrap them for two inches. Looping the wires will not do. Be careful to scrape with a knife or stone the wire ends to make them bright before wrapping them together. Corroded or dirty connections are a cause of misfires.

Wire Connections

If the leading wire gets broken and must be spliced, solder the connection after wrapping the ends together, then wrap the joint with tape to

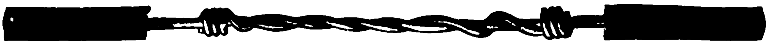
insulate it. Ordinary tire-tape is good, but a better way is to wrap the joints with special rubber tape underneath and to cover this with the tire-tape.



Tape for wrapping joints and broken insulation.

When only one charge is to be fired, connect the ends of the 2 strands of the leading wire to the 2 electric blasting cap wires and connect the other leading wire end to the blasting machine posts. The connection with the electrical blasting machine should be made the last thing before firing, after you are sure that the charges are all ready and after every person and animal is out of the way of the flying pieces.

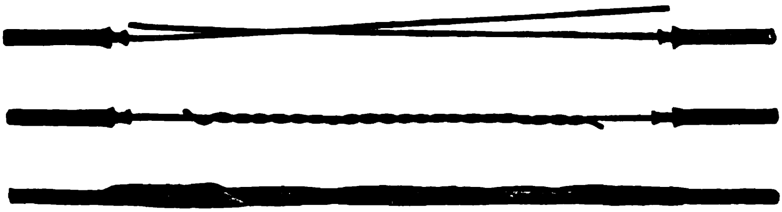
When the blast is all connected together ready to fire, except attaching the leading wire to the machine, give the handle of the machine one or two light strokes, to make sure that it is working smoothly and to charge the magnets. Then attach the leading wires to the binding posts on the machine, making sure that both the binding posts and the wires are bright and clean where they come together. Raise the handle of the machine to its full height and push it down with speed. When the handle starts on its downward stroke, the pinion immediately clutches the armature and starts the generation of current. The current, growing stronger as the stroke proceeds, causes considerable resistance toward the end of the stroke. The current generated is directly in proportion to the speed with which the handle is pushed down, especially just before reaching the bottom. Any let up toward the bottom will cause a drop in the current and may result in misfires. Therefore, make it an invariable rule, whether the shot be large or small, to bang the handle down hard and carry the stroke with all possible speed to the bottom. Try to knock the bottom out of the box. Machines which operate by the twisting of a handle must be handled equally quick.



Very best wire connection, ready for soldering if need be. (Excellent for leading wire.)

When more than one charge is to be fired the different charges must be connected together. The diagrams will help you to understand how this should be done. For nearly all agricultural blasting the connection in one series is the best—that is, connecting each charge to the next one and so on until they are all joined, with one loose electric blasting cap wire from the two end charges of the series. (See diagram A and D, page 163.)

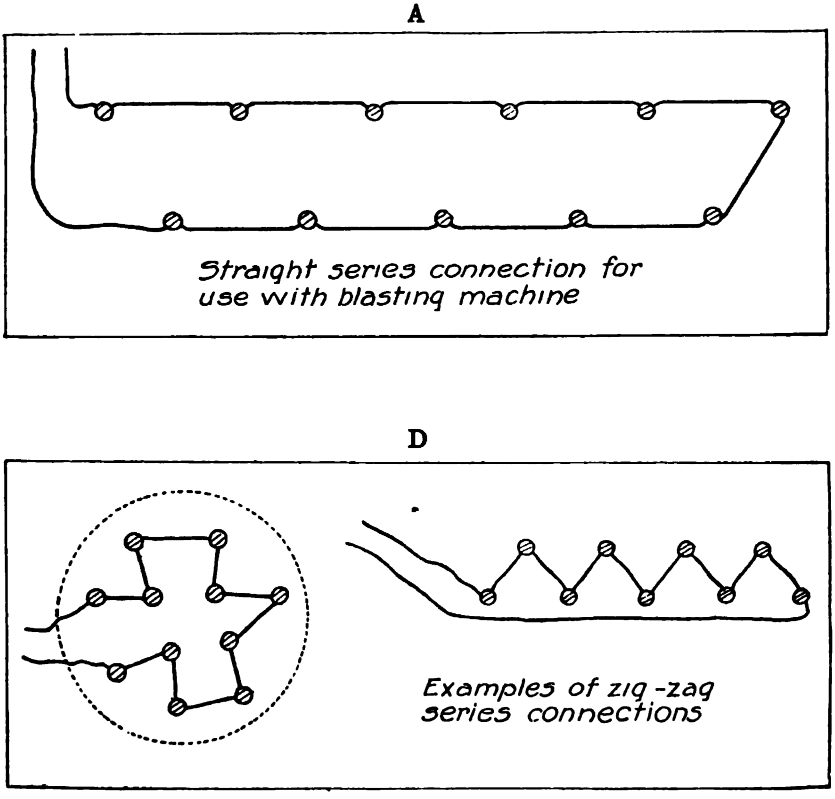
Once in a while, where the series is long and the charges are in a line, you can arrange to have the 2 loose wires at the same end of the series by making the connection, not to each next charge in the row, but to the one beyond and at the farther end doubling back and connecting the missed charges. Do not use this method where it involves many splices with connecting wire.



Method of wrapping wires together to make electrical joint, and taping joint.

Current Required

In a bulletin of this size it is impossible to give a comprehensive statement of electric firing. But to give some idea, it can be stated that an electric blasting cap requires 1 to 1½ amperes to insure firing. This amount of current will fire one cap or many in a series. To force this amount of current through the wires requires a certain voltage, the amount depending on the size and length of all the wires, and on the joints. One bad or poorly wrapped joint will increase the resistance of the circuit more than several caps. The voltage of the current required to fire any circuit usually can be computed by an expert when the details of the wiring system are explained to him.


A
Straight series connection for use with blasting machine
D
Examples of zig-zag series connections

Ways of connecting up charges for electric firing.

Electric blasting machines are constructed to give a sufficient amperage and voltage for firing properly the number of caps specified as the capacity of the machine when connected in a series. If too many caps, or more than usual wiring is connected to any machine, misfires will result. Other current can be used in place of that supplied by a machine, provided it has enough and not too much amperage and voltage. Too great a current will burn out wires without firing all the charges. Too little current sometimes may fire a part of the charges or none.

Two post electric blasting machine

Bare connections at the charges or back along the leading wire should be raised off the ground by stones, sticks or piles of dirt placed under insulated parts of the wires at each side of the splice. During a thunder storm, do not stand near any of the charges that have been connected. Avoid dragging the leading wire over bare or rough ground as much as possible, and particularly avoid kinking it. Be careful not to break or tear or scratch the insulation of any wires.

Do not attempt to fire through a long length of leading wire wound in a coil or on a reel. The induction, leakage or short circuit of current in the coil of wire causes the blasting machine to deliver a slow discharge, which is fatal to proper firing. Leading wire that is water-soaked or that is covered with mud will lose a considerable part of its current.

Misfires

Many of the accidents noted each year in blasting operations are the result of attempting to examine misfires too soon. If misfires occur with fuse firing, stay away from the shot at least 2 hours. It is better to wait until the next day, for the spark may linger 24 hours and still cause an explosion. (See page 151.) Rock and stump misfires are to be avoided especially. When you are firing the charges electrically, you may approach the shot in fifteen minutes after an attempt has been made to fire the shot.

Misfires are due to the following named causes. The remedies for them are care in preparing the charges and in loading, the details of which are given in the proper chapters.

With cap and fuse firing, misfires are caused by having the end of fuse pulled back a little from the bottom of the cap, by crimping the fuse too tightly with a groove crimp and shutting off the spark, by damp or wet fuse, especially at the end of the cap, by defective cap, by the cap getting pulled out of the explosive, by kinked, damaged, broken or pinched fuse, by failure to light fuse. A great many misfires were never fired at all. With electric firing the reasons for misfires may be damaged wires in the hole, causing short circuits, defective caps, overloaded blasting machine (trying to fire a greater number of electric blasting caps than the machine is designed for), cap pulled out of explosive, bad wire connection at some point, or broken wire.

If you find after due time that for some reason the charge cannot be fired by lighting the old fuse or by sending current through the wires, you must deal with a real misfire.

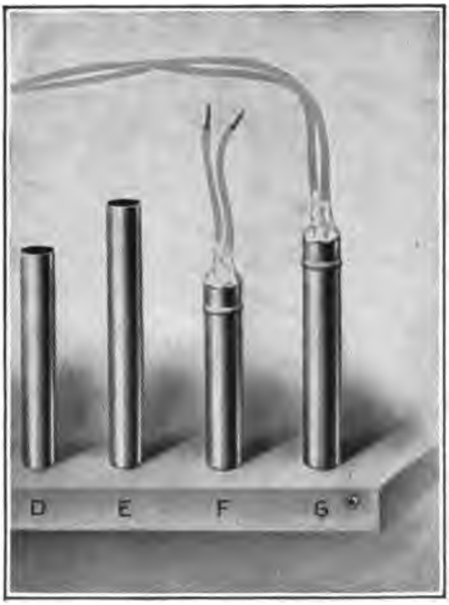
The best thing to do is to put in another, lighter charge in a new hole made 6 to 12 inches from the original one. The explosion of the new charge will explode

the old one. Never touch the tamping in the old hole unless you know just how deep it is, or how many inches of it there are above the charge. Once in a while the tamping may be dug out of a blockhole misfire. It seldom pays to do this in stump blasting, and never in ditching, or soil blasting. At best it is a dangerous operation. Mudcap charges can be opened and new primers inserted without danger or difficulty. This should be done by removing part of the mud at another point, and inserting a new cap and fuse, or electric blasting cap, as the case may be.

Cap (Detonators)

Blasting caps are little copper tubes closed at one end, 1½ to 2 inches long and something less than a quarter of an inch in diameter. At the bottom is placed several grains of a high explosive that is very powerful and exceedingly sensitive to heat, shock and friction. This high explosive usually is fulminate of mercury, but often is other material. They are packed in small tin boxes, open end up, usually 100 to the box.

The purpose of the blasting cap is to supply the shock and heat necessary to detonate the charge of dynamite to be fired. So sensitive is the detonating material that it would be impossible to handle the little bit of explosive in the caps if it were not protected by the copper shell. Even at that caps must be kept free from jars and from heat and sparks to avoid premature explosion.

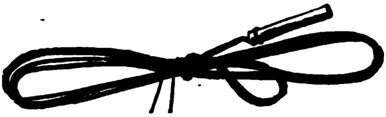


D and E are ordinary blasting caps; F and G are electric blasting caps, often called fuzes.

The strength of caps is carefully regulated by the makers to fire the dynamites and powders on the market. The explosive material with which the caps are loaded is such as will deliver a shock and a degree of heat of the strength and violence required. The caps are numbered according to strength. All dynamites and powders used for agricultural blasting require at least a No. 6 cap. If they are chilled a little, but not frozen, they require No. 8. It is the part of wisdom to use No. 8 caps all the time, especially for propagated ditch blasting, if you can get them. They give you a margin of strength should moisture or other causes weaken them in storage.

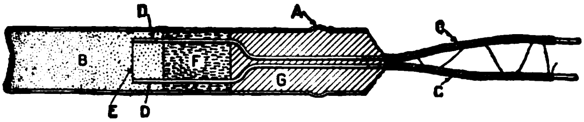
Blasting caps must be used with fuse. And before they are inserted in the cartridge of explosive they must be fixed to the fuse properly. (See pages 144 to 147.) It is the spark which travels down the fuse that fires the cap.

Electric blasting caps are made on the same principle as ordinary blasting caps. They have the copper tube, the explosive at the bottom, etc., but they differ in the way this explosive is fired. Instead of by a powder spark they are fired by a red-hot wire that is heated by an electric current.



Electric blasting cap or fuze.

Every electric blasting cap has fitted in it 2 small copper wires, which must be considered part of the cap. Down near the bottom of the cap is a delicate bridge of finer wire. The entire arrangement is held in adjustment and sealed by a casting of sulphur-like substance.



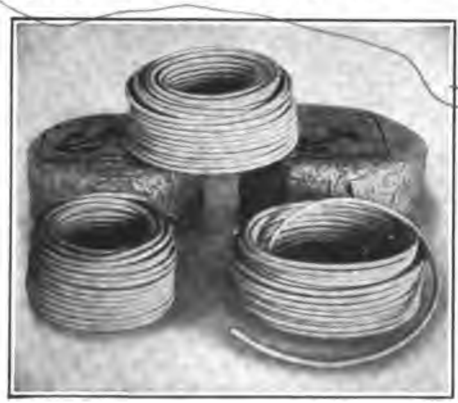
The interior construction of an electric blasting cap or fuze.

For fuse blasting you must use regular blasting caps, and for electric blasting you must use electric blasting caps. It is impossible to substitute one for the other. Never pull at the wires in an electric cap. It is dangerous and may loosen or throw out of adjustment the arrangement of wires inside. And never try to dig out the wires of an electric cap or to dig or to punch the explosive in the bottom of a blasting cap.

Fuse (Safety Fuse)

Fuse is used for firing black blasting powder and for firing dynamite and high explosive powders through the medium of a cap. It is made by enclosing within a covering a train of special black powder and an inflammable cotton string. The spark runs down this powder train.

The powder used in fuse is specially made for the purpose, is pulverized and is highly compressed by the covering of the fuse. The covering itself is made of varying materials, depending on the conditions under which the fuse is to be used. For dry work it is only enough to hold the powder in place and to keep the powder train from getting broken. For damp and wet work it is made waterproof by increasing the number of layers in the covering and by adding varnish, coal tar, as other waterproofing material.



Fuse as it comes in rolls.

Grades

There are many brands of fuse on the market. In buying fuse you must bear in mind the character of your work. For work that is entirely dry you can use ordinary cotton or hemp fuse with satisfaction, if it is large enough to fit a blasting cap snugly.

For work in damp ground, use a fuse in which the cotton or hemp is covered with one layer of waterproof tape or other material. This is called single-tape grade or may be known by brand name only. For work where the ground is wet, such as in stump and stone blasting in damp or wet weather, use a double-covered fuse—fuse that has two layers of tape or other material over the cotton

covering and waterproofing material added. For work where water covers the charges it is best to use fuse with three layers of tape or other material and full waterproofing. This is called triple-tape fuse or may have special brand names. When buying fuse for general farm work, it is well to get a waterproof grade, since it can be used for both wet and dry work.

Rate of Burning

Most reliable fuse burns about 2 feet per minute when in perfect condition. If it becomes damp, it burns much slower. Cases have been known where the spark smouldered in damp fuse for hours without traveling more than a few inches. Another source of uncertainty is where fuse has been pinched. It may take the spark a minute or an hour or a day to get past the pinched point.

When fuse is cold, it is hard and brittle, and may crack open when unrolled. If it gets too warm, its waterproofing material may penetrate to the powder train inside and ruin it; or the covering may first soften and then harden, in this condition breaking as though cold when unrolled. If grease is allowed on the cover it may combine with the waterproofing and ruin the powder inside.

Handling Explosives

Dynamites in boxes can be hauled freely in spring wagons or auto truck. You should see that no bolt heads or other metal parts project from the wagon boxes to strike the boxes of explosives. Sweep all dirt out of the wagon. Have the beds clean or covered with straw or blankets.

Go over your wagon and harness before you load dynamite to make sure they will not break down while you have the explosive aboard. Be sure you have the hitching straps or tie-ropes along, and do not leave the horses standing without tying them securely. Break no colts while hauling explosives. If you use a motor, stop it and set the brake tight before you leave the load. In driving through a town stay away from dangerous crossings.

Keep the cartridges of explosive in their original boxes until you are ready to use them. Don't have them around loose. In carrying them to the field, use a wood basket or a box and not a metal bucket. Always protect explosives from all possibility of being reached by falling sparks or from match heads or other source of fire. Rain, hot sun and the like must be kept away from explosives. Use care to lay cartridges or set the boxes or baskets containing explosives where they will not fall down, be blown over by wind or knocked over by careless people or by animals. Cattle will eat cartridges of dynamite because of their sweet and salty taste. The explosive will make them sick, sometimes kill them.

Since nitroglycerin often will cause headache when absorbed through the skin it is best to wear gloves when handling the cartridges. For this same reason some people punch holes for caps in the cartridges with a piece of wood rather than with the handle of the cap crimper.

Caps should not be carried in the same basket or box as explosive, but should be carried separately. Take only enough along to do the work in view and carry them in the tin boxes they come in. Many serious accidents have been caused by blasters having loose caps in their pockets during work or afterwards. Sooner or later a chance jar is likely to set them off. When several caps have been taken out of the little tin box in which they come the rest will be loose and will rattle about. This should be stopped by filling up the empty space with paper.

The handling of caps is not dangerous provided you do it intelligently and with care. *Keep them safe from any jars or heat.* You can sometimes do

Handling many foolish things with dynamite without serious results to yourself, but not with caps. Letting a cap fall to the ground or floor likely will cause it to explode. For this reason you should keep the caps and explosives apart, in hauling, storing, and handling, bringing them together only at the last minute before you prepare the charge to be loaded in the hole. One cap can produce an explosion powerful enough to tear your hands off.

Electric blasting caps must be handled with the same care as regular blasting caps. All caps must be protected from dampness during handling. No trouble will be experienced if you use common sense at every turn, but thoughtlessness and carelessness in the handling of explosives will cause disaster. Bear in mind that when an accident happens with an explosive there is no time to save yourself, and no afterthought will prevent serious injury to you. Forethought is the thing with explosives. In an explosive you are handling an enormous strength. The fact that it occupies small bulk now should not interfere with your imagining it as an enormous engine with power enough to crush you easily, but under entire control if you do your part right.

Storing Explosives and Supplies

The storing of dynamites on farms offers no serious problems, though it may call for some shifting of arrangements to meet proper requirements. The explosives must be kept dry. They should be kept cool. This means that any ordinary temperature of the air is all right, except that in hot weather the room where the explosive is kept should not get warmer than 80 or 90 degrees. If it is properly ventilated day and night it will not. Probably the best common storage place for explosive is in an outbuilding under the floor of which the air circulates freely and with a ceiling between the room and the roof. It should be strong, and should be provided with a lock. A responsible person should have charge of the key at all times.

The explosive should not be kept in a garret, because the hot sun beating down on a roof will raise the temperature under the roof away past the 100 degree mark.

Dampness is injurious to explosives, as noted on page 143, and dynamites and powders must be kept where moist air will not surround them. The ideal storage would be fireproof, but since this is out of the question on the average farm, the best that can be done in that respect is to guard against fire. It is well to make sure that the explosive is out of reach of any stray or malicious bullet that might be fired into it.

Look to your insurance policies and see whether they provide against the storage of explosives in any of your buildings. Store the explosive in a building not covered by the insurance.

Magazines Where large quantities of explosives are to be stored as a regular thing, or for any length of time, it is advisable to consult the makers of explosives or others experienced in their handling in regard to the location and construction of a magazine. A magazine can be set up cheaply and can be made fireproof, bullet proof, thief proof, well ventilated, dry and safe in every way. It should be built of brick. Any explosive maker will furnish plans without charge. In any case explosives should be stored at least 50 yards away from any other buildings and from roads or railroads.

Blasting caps of any kind must not be stored with dynamite or powder. Fuse is not explosive and can be stored with dynamite or powder.

Caps

Blasting caps are even more subject to damage by moisture than explosive and must be stored accordingly. Caps must not be allowed to become heated.

A statement of the ways in which explosive deteriorates will help in selecting a proper storage place for it. In temperatures higher than 80 degrees troubles may begin. Long continued temperatures of 90 to 100 degrees may cause the nitroglycerin to leak out of the absorbing material and to gather inside the wrapping on the lower side of the cartridges, or may even cause it to leak out of the wrappings through the boxes and to the floor.

Deterioration

Strict watch should be kept of the cartridges and the boxes to catch any such condition. If leakage occurs, turn the explosive over and reduce the temperature. Burn the empty boxes one or two at a time out away from buildings, and scrub the floor where the leakage occurred with a strong solution of sal soda. This will decompose the nitroglycerin. If it becomes necessary to destroy a little explosive without detonating it, the job can be done by immersing it until dissolved in such a solution, stirring it gently with a wood paddle.

If the cartridges feel smeary it is possible they are leaking. The test is to lay them on white paper for a little while. If they are leaking they will stain the paper, otherwise not.

At a temperature of 105 degrees nitroglycerin explosives will lose 10% of their strength in a few days by evaporation. Repeated freezing and thawing is bad for explosives, especially if the thawing is rapid. Slow thawing will not damage them. After explosive once is frozen and thawed, it will freeze much easier again.

When stored for many months explosives are liable to decomposition of some of their elements, especially if they get damp or too warm. One of the marks of this is greenish stains inside the cartridge wrappings. No length of time can be stated for the keeping of explosives, because it practically all depends on conditions. Under favorable conditions most dynamites and powders will remain in good shape for years. Again, a month of improper storage will ruin them and make them dangerous to handle. They develop troubles sooner in the light than in the dark.

Deteriorated explosives are likely to be dangerous—far more so than normal explosive. Keep watch over what you have in stock. Maintain proper conditions as far as possible, but if they show troubles do not hesitate to condemn them.

Shipping Explosives

The shipping of high explosives is controlled by the Interstate Commerce Commission, and the rules and regulations are very strict and rigid. Most of them are embodied in an Act of Congress of March 4, 1909, and violations are punishable with fines of not more than $2,000, or imprisonment for not more than eighteen months, or both. The person making the shipment is responsible.

A copy of the rules and regulations can be secured from the Bureau of Explosives, 30 Vesey Street, New York City, or can be read at any freight station where there is an agent.

The rules provide that no explosives (other than certain exceptions named) shall be carried on any train, boat, trolley, or other vehicle carrying passengers

for hire, and that no explosives under deceptive or false markings or understanding shall be delivered to a common carrier; and further, that all other regulations shall be complied with.

In shipping by railroad no caps or detonators of any kind can be sent in the same car with explosives. In practice the railroads usually send them by another train, which works out to be another day in the cases of nearly all shipments. This is responsible for some delay in delivery of explosive shipments. Do not expect to have explosives come through as quickly as you would other freight.

Explosives cannot be shipped by express or by mail, but are sent by freight. The railroad company is required to place the packages in a certain way inside the car and to brace them with lumber. In case of car-lot shipments the shipper must furnish this lumber and do the bracing.

The regulations provide that railroads must have 24 hours' notice of shipment of explosives, *and that shipments must be removed from the receiving station within 24 hours of their arrival there.* The packages must be plainly stenciled with the name of shipper and consignee, and bills of lading must conform with certain specifications.

Empty boxes which once have contained explosives must never again be used for shipments of any kind. Farmers who have attempted to ship vegetables or other farm products in such boxes have unwittingly gotten themselves into trouble on account of this regulation more than once.

Danger and Safety

Modern explosives have been developed to the point where they need not be feared by anyone who handles them intelligently. Speaking in a comparative way, they may be used with no greater dangers than there is in the using of horses, mowers, traction engines, sawmills, or other farm equipment, or than there is in using shotguns or rifles.

The general use of explosives on farms is so new that many people distrust them more because of their newness than from a clear understanding of any actual dangers their use may hold. A review of what the dangers are may help users of explosives to avoid them, and may help to build up the reader's belief in the *safety* of explosives.

There is some danger in the handling and transporting of explosives, but it depends very largely on the exposure of the dynamite or powder to heat, flame, sparks, blows and friction. The directions say to keep explosives dry, to keep them at a temperature less than 90 or 100 degrees F., to keep them safe from sparks, and to avoid blows and shocks. If these directions are followed there will be few accidents.

Probably the most common cause of accidents with explosives lies in violation of some of these primary rules while thawing frozen cartridges of dynamite. Freezing makes the high explosive less sensitive to the simple direct shock of a blasting cap, unaccompanied, as it is, by any friction. But at the same time freezing makes the explosive more sensitive to friction in any form.

For this reason, though a frozen cartridge of dynamite cannot be fired properly by a blasting cap, it is very likely to be fired prematurely by a chance light blow from any object touching it, by your slitting the wrapping paper with a knife, by breaking the cartridge in two, or by attempting to punch a hole into it to insert a cap. (These operations are entirely safe when the explosive is normal.) If the cartridge is dipped in warm water or exposed to steam, or is laid on anything which is warmer than about 125 degrees, free nitroglycerin likely will leak out

and fall in drops. And one drop of nitroglycerin falling only a few inches may be exploded itself and may explode all dynamite that is near it.

Throughout the entire course of handling the explosive, from the freight station to the hole in the stone or the ground, you should remember the five cautions which will be repeated: Keep it dry, keep it cool, keep it away from sparks and flame, and keep it safe from blows and friction. Be careful—as careful as you would in driving a big automobile or a traction engine. Then you will be secure from any accidents, and explosives will be safe to handle.

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The Use of Explosives in Making Ditches

By J. R. MATTERN

Published by
The Institute of Makers of Explosives
103 Park Avenue, New York City

Compliments of
HERCULES POWDER CO.

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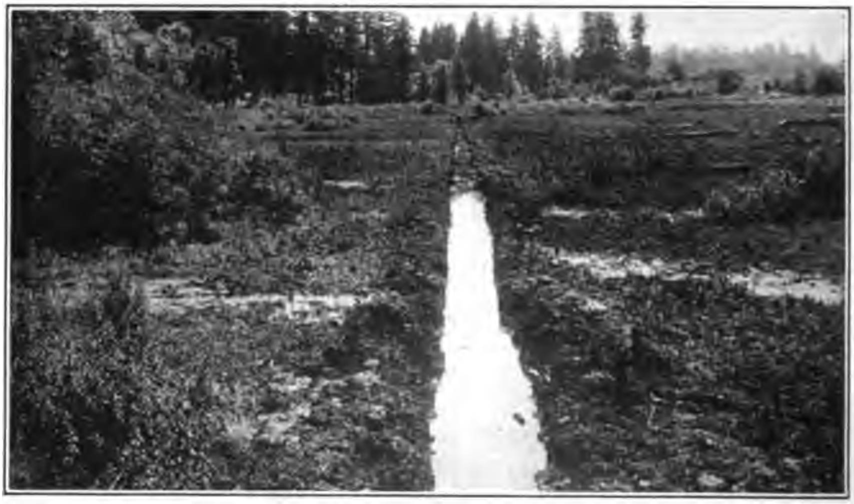
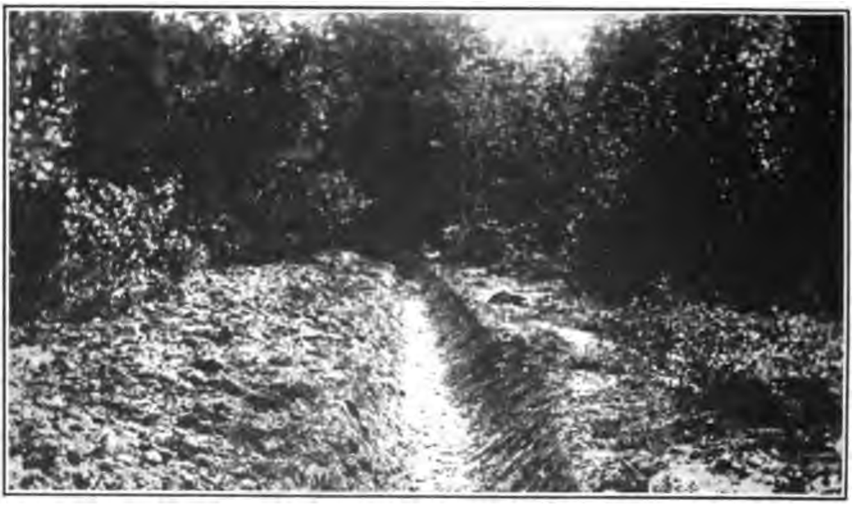
INTRODUCTORY

THIS bulletin is published by the Institute of Makers of Explosives. It is not intended to sell anything, or in any sense as a piece of sales literature, but as a manual or handbook for those who drain land and make ditches, and possibly as a textbook for students of agriculture and rural engineering.

Ever since the blasting of ditches has become standard practice there has been need of some book of reference containing the essential facts about the use of explosives in the making of ditches, eliminating untried theory and conflict of opinion so often found in less complete publications on the subject.

Sufficient knowledge and experience in the use of explosives for this purpose have been accumulated. The time has come when such a book can be prepared authoritatively.





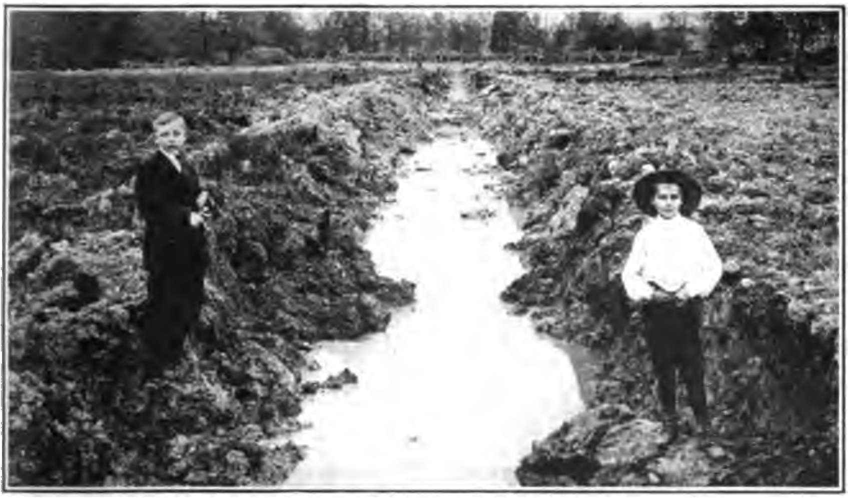
These ditches show the result of cutting the sod and the earth along the sides before the blasting. Shovel blades, axes and a hay-knife were used. A man cut a rod along one side in about two minutes. The blast left the soil outside of the cut firm and intact, while scooping the contents of the ditch out clean. (Upper, Miller Drainage District, Marion Co., Oregon; lower, Connecticut land of Polytechnic Institute of Brooklyn.)

The Matter of Farm Drainage

Much draining of agricultural land has been neglected because it has demanded so much money, time and hard work, and so many men. The excessive cost of ditching has retarded plans to drain, and poor methods have retarded actual construction.

In times past ditches have been made largely by hand shoveling. A few of them have been plowed out when shallow ditches could be made to do the work at all. But the digging of a few hundred yards of ditch 3 feet deep has been a summer's work on a farm, and the draining of land always has been very expensive and hard.

With the increase in the cost of labor, and the scarcity of farm help compared to the numbers of men that used to be available, there is serious need for means of draining that are easier, quicker and cheaper. Since ditching with explosives has become well known and generally practiced, it has come to be the desired method.



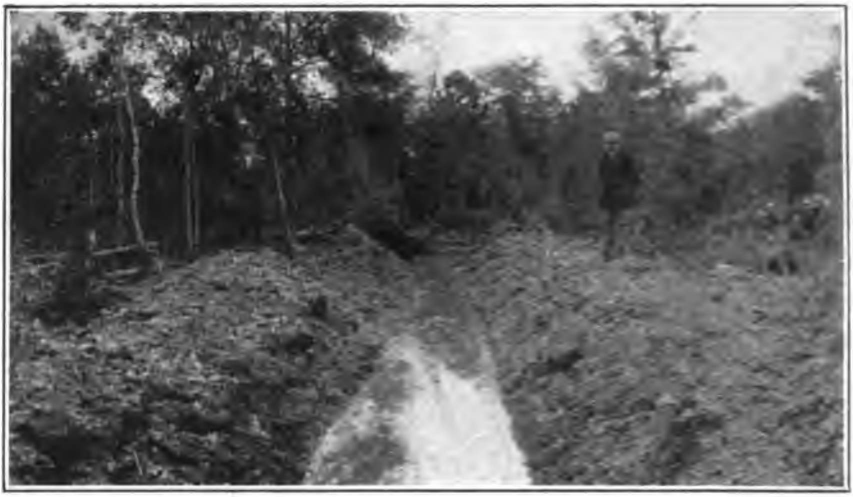
Observe the even spreading of excavated earth over the surrounding ground, leaving little elevated bank on the edges of the ditch. Even in heavy, stiff clay such as this, the explosion grinds the earth up pretty fine. (Chester Co., Pa.)

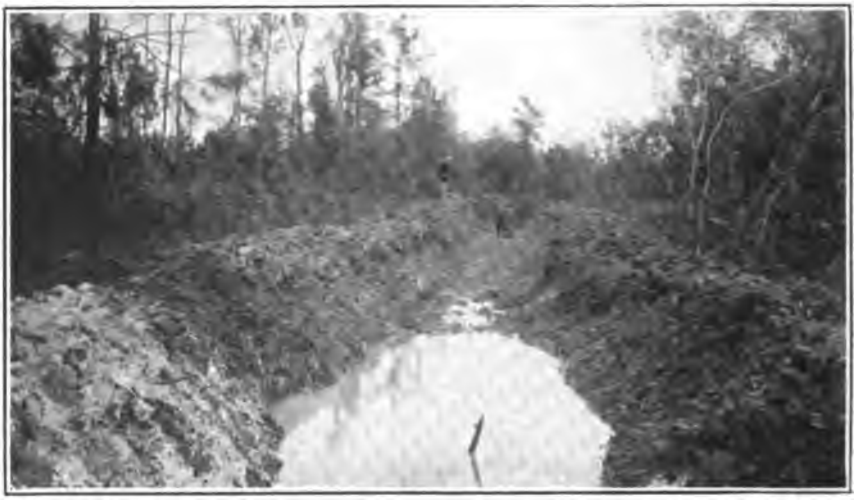
With few exceptions, ditches can be excavated with explosives anywhere. The nub of the whole matter lies in the fact that one of the cheapest ways of moving dirt known is with explosives.

To blast ditches practically all that is necessary is to punch lines of holes and push charges to the bottom. The sides and bottoms of the blasted ditches are not as smooth as if they were shoveled out, but they are even and true, and the flow of water soon levels them down and smooths the bottoms.

The work can be done quickly, neatly and with no expensive outfit. It calls for few men. A month's work by ordinary methods can be done in a day, or a week's work in an hour. Ditches can be blasted through any kind of ground except dry sand. The presence of brush, grass, stumps and stones is no bar to this method of cutting out the ditches, though of course they dig out smoother and cheaper when the nature of the ground is clean and clear.

As for size, ditches of almost any desired depth greater than 1½ feet and any ordinary width greater than 3½ feet can be blasted out. Ditches in fields





Representative blasted ditches in sandy loam of the Atlantic Coast section. In such material the charges must bo heavy and must bo skillfully placed to produce the perfect results shown. With proper care the excavation is satisfactory and the sides more even and true than in clay soils.
(Charleston, S. C.)

and along roads, ponds, canals for drainage or boats, stream channels and similar cuts for any purpose can be blasted out.

This book explains the possibilities of blasting and makes clear the basis on which choice of a method for your work should rest. It shows how to plan and to lay out drainage systems, and how to construct open ditches to the best advantage. Other methods than blasting are recommended frankly when conditions and purposes are such that can be used to the best advantage.

Conditions Demanding Drainage

Two classes of farm land should be drained. One is the usual swamp land where the ground is saturated with water or at least is too wet for the growth of cultivated plants. The other class is land now cultivated, but which at some part of the year carries excess water.

The wet or damp lands may be merely low spots in fields, or may be entire valleys. Low spots often can be dried by cutting a ditch through rims of higher ground surrounding. If the wet condition is caused by overflow from streams, the stream channels should be deepened or widened till they carry all the water. If seepage from springs on the land or above it causes the trouble, a ditch cut across the flow of the seepage water will be the proper remedy. If the water-table is too high, a big open drain may gather and carry away the surplus, lowering the surface of the ground water to where it will not interfere with roots.

On account of the matter of moisture storage, as well as on account of general fertility, all land which is cultivated should be drained thoroughly of excess water. It is not enough to reduce the surplus to a point where meadow grass will grow; the drainage must be sufficient to dry off the ground soon after each rain and soon in the spring.

Roads always must be well drained if they are to remain solid and hold their shape in wet weather. Crooked streams should be straightened, to prevent cutting of the banks and overflowing, and ditches and streams too shallow or small to carry the volume of water present should be deepened or widened. Swamp conditions are a menace to health, breeding mosquitoes and their attending diseases. It often pays to drain lowlands where water stagnates, from the standpoint of health and comfort alone, when they are worthless for any agricultural purpose.

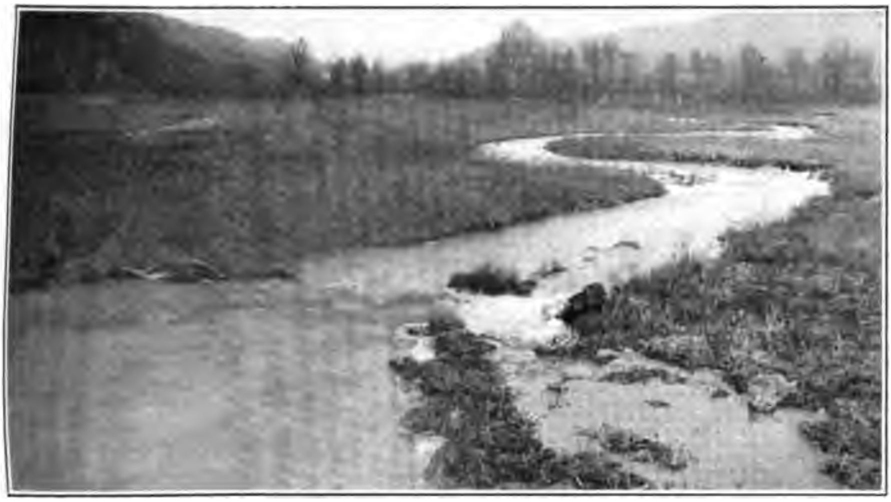
The Value of Drainage

Good drainage not only removes surplus water but actually helps to store moisture against dry weather. When soil is choked with water, deep rooting of plants or trees is impossible, and the soil processes which make available the plant food are hindered or altogether prevented. It is the absence of air almost as much as the presence of the water that does the damage. The better land is drained to a proper depth in each case, the finer and more mellow and crumbling it will be, and the more of useful moisture it will hold in the summer.

Swamp land usually is very fertile when the excess water is removed, and will grow wonderful crops. It contains a rich supply of plant food. Such land must be aerated—drained—and limed before its fertility can be used.

The direct loss of income from the idle acres in swamps can be figured by anyone. But this is not the only loss. There is the decreased net profit from other land that is farmed under the same ownership. The swamp land costs interest on its purchase price and taxes every year. This cost must be paid by the productive acres.

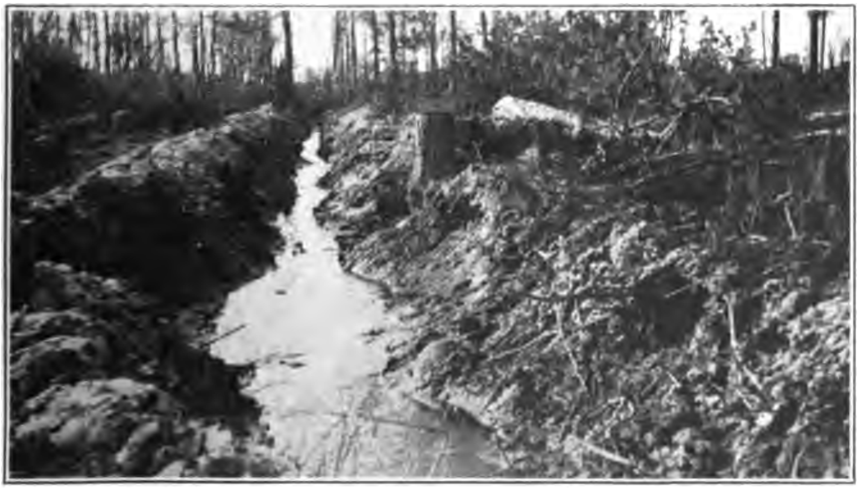
Two pictures that tell a story of swamp grass damming up a stream, which backs up and floods a field, ruining the hay, or corn or any other crop which may happen to be there. To dig out by hand or plow out such a clogged stream-bed is difficult and expensive, but to blast it out is the work of one man for an hour or so, at a comparatively small cost. (Mud Lick Farm, Julian, Center Co., Pa.)



Winding streams cut up and waste much land. They change their courses every year or so, tear away the banks at the curves, gouge out deep holes and build up sand bars. They occupy many times the area they would if straight, and practically ruin the soil which is worked over by the water. (Mud Lick Farm, Julian, Center Co., Pa.)

There is another feature of the matter that ordinarily is overlooked. This is the black eye which the farm is given by a ragged-looking piece of swamp land touching the clean acres. Whether the farm is on the market or is to be kept as a home, the waste lands cut down its value and damage its reputation among all who see it, including the stranger passing by, the neighbors over the fences and the man who lives on it.

It is a well-known fact that malaria disappears when mosquito bites are eliminated, and that the mosquitoes can be eliminated by draining the swamps.



The excavation done by a single line of charges of explosive properly placed in watersoaked clay soil is remarkable. The ditch resulting sometimes is two-thirds as deep as it is wide at the top. The bottom is U-shaped.

In the lowland sections of the country this has been done with great success. Even in the flat lands joining the ocean where tide water sometimes washes in over land and makes ponds, the opening cut of channels has drained away the water and killed off the mosquitoes.

Other enemies that breed and lurk in swamps are weeds and predatory animals. The seed weeds in the swamps pollute all the surrounding land, and the cleaning up of the swamp is a favor and a benefit to the entire neighborhood.

Horses and cattle often get mired into the soft mud and are unable to get out without help. They may stick there and starve if not discovered and pulled out, or they may break a leg, or sprain themselves in their struggles.

One of the meanest things a farmer has to do is to haul loads of hay, grain, manure or fertilizer through a swampy place in the field. The remedy is to open a ditch through the center, after which the soft ground will harden up and the ditch can be bridged.

But not all wet land should be or can be drained. In general whether it will pay to drain or not will depend on how cheaply the job can be done, though this is such an indefinite rule that it is not of much value. Many a drainage job that can be done for $50 to $75 will add $100 to $200 to the value of a property. From a financial standpoint, a man is not justified in spending more money than the crops that can be grown will return in a reasonable number of years, though other considerations may make it wise to spend more.

The Essentials of Successful Ditching

It is well to have a clear idea of what to require of a ditch before attempting to complete the plans for it.

The successful drainage ditch should be straight, to give an even, swift flow of water without cutting out the banks or filling up the bottom. Its sides and bottom should be smooth and true, both to facilitate the flow and for appearance. It must be deep enough to put the water-table at a proper level. It must be wide enough to give the capacity required by the volume of water to be carried in flood times. The grade, of course, must be enough to carry the water away and to make the drainage action sure.

The excavated material ought to be well scattered and spread evenly over the surrounding land, without leaving a ridge or dyke along the sides of the ditch. When this material is piled up along the ditch it takes up ground space and acts as a dam for surface water and compacts the subsoil beneath by its weight, making the drainage of the fields much slower. Finally,

One of the best demonstrations of the value and success of the blasting of ditches is in cutting a large channel through difficult ground for a short distance, as this picture shows. One man can do the work in a couple of hours. The expense is not to be compared to the cost of cutting the same ditch by plowing, hand shoveling or machine work.

(Valley Creek, Pa.)

the ditch in respect to cost, time and men needed for construction, must come within the available limits. The cost must be low, the time of construction short, the men required few, and the work not unreasonably hard. Frequently if the ditching is to be done at all it must be by only two or three men in what practically amounts to spare time.

The line of the ditch follows the line of the charges faithfully, making true curves and angles. It should be the policy to eliminate all twists and to make the ditch as straight as a string whenever possible. (Chester Co., Pa.)

There of course are many large agricultural, road, lumbering and other enterprises to which these remarks do not apply, because the ditching must be done and men are hired for the purpose. The managers of such propositions are fortunate in having eliminated for them one of the chief difficulties of farmers.

Ditches, canals and other such excavations not intended for drainage do not differ much in requirements from drainage projects. Cost, time and labor required always are the important considerations.

Nature of the Ground

The reasons why land is wet are few. There may be a layer of ground a few inches or a few feet under the surface, holding the water from escaping downward. The topsoil itself may be of such a nature as to prevent water from percolating through it. The water may keep rising from springs, producing the condition called seepage or spouty land. Again, the water-table, or height of the surface of a nearby large stream or lake or bay, may be nearly up to the surface of the ground, or the stream or ditch carrying away the water may be too small or too high at its mouth.

The nature of the ground must be considered in deciding on the method of ditching. Sand, for instance, is easiest to handle by some methods, and hardest by others. Dry ground handles cheapest in some ways and most expensively in others. In ditching you are likely to encounter hardpan, gravel of all sizes, both loose and in solid beds, and every kind of mixture of these materials. Each of these conditions calls for its own sort of treatment.

A ditch blasted through very dry ground without any side cutting. The result is not altogether a success, since the excavation is reduced in amount and is incomplete, and the cost is high. The soil is coarse sandy loam with much clay beneath. The blasting would have been much more successful if the ground had been full of water and the sides of the ditch cut before the blasting was done. (Near Snow Hill, Md.)

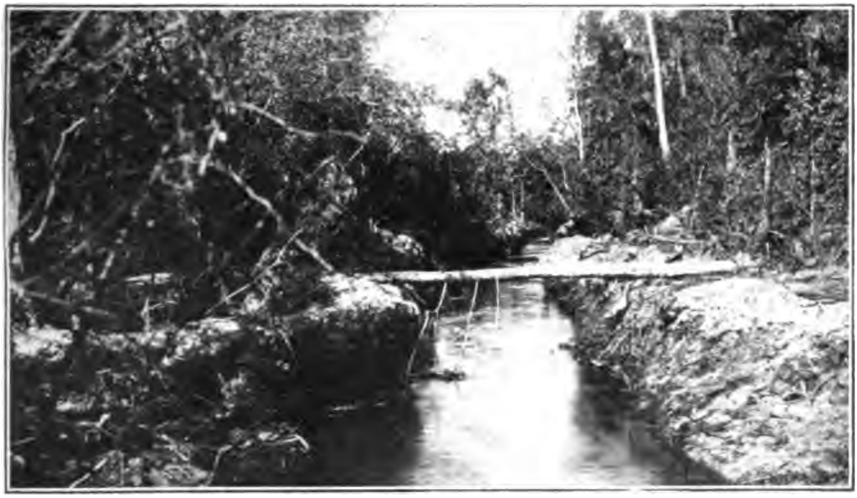
Heavy charging and skillful management will blast out a very good ditch through extremely difficult ground. Here the soil was matted with green roots. Some of them are left projecting into the ditch, but most of them are broken off and thrown out. The excavation of earth was very complete, owing to its watersoaked condition. (Georgia.)

Choosing a Method of Draining

The methods that are available for making ditches are:

- Shoveling by hand,
- Plowing,
- Trenching with machine equipped for excavating,
- Blasting.

Each method has its place. In choosing a method many considerations enter into a wise decision. The purpose for which the ditch is made—whether open ditch or underdrain, canal for water or boats, and the like, must determine the character of the ditch. The kind of soil, the size of the ditch, the amount and kind of obstructions, the time available before the job must be finished, the men that can be put on the job, the capital available for labor and equipment, the source of the water to be drained away, the height of the water-table, the use of the land to be drained, the amount of water to be carried and the fall of the land —all these factors have a bearing on the selection of the method of making a ditch.



Note the projecting knobs of earth held by matted roots of trees and brush. Such irregularities in the sides of a ditch are not a disadvantage except in appearance in a ditch where the flow of water is heavy and swift. But when the volume of water is small and the fall slight the edges should be smooth and straight.

Tile Drains

No open ditch through cultivated land should be considered when conditions are such as to make underdrains better, and when money is available for constructing them.

But in a great many places the nature of the ground or water flow is such as to require open ditches. In other places they are just as good as closed drains. For instance, through pasture land and woods an open ditch will do just as well as an underdrain and better where there is a spring or brook which overflows at times. In muck land closed drains are not practicable.

Ditches for immediate laying of tile cannot be blasted out with satisfaction; the bottoms are left too soft to hold the pipe properly. If funds for tile draining are not available immediately, an open ditch can be made by blasting which, after a couple of years, will be entirely satisfactory for tiling, though

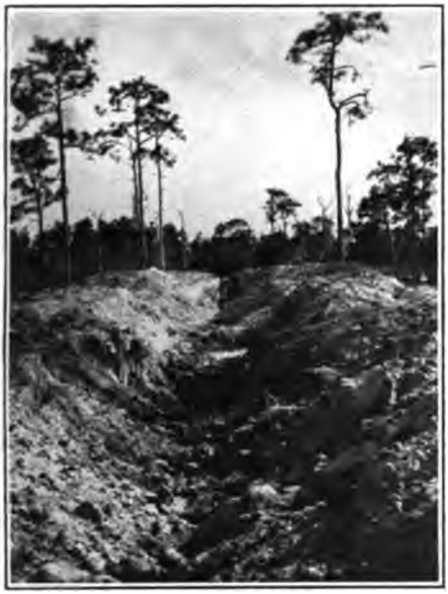
Proper blasting will open a channel through thick brush and grass, though such a ditch will not measure nearly so much in the clear as though the land was clean and free from roots. You can blast channels for boats or for drainage through a marsh where the ground is under water. (Kentucky.)

the earth required to refill the ditch will be scattered widely. Light blasting very often is desirable, however, to loosen hard ground in order to make digging of tile ditches by other methods easier.

Open Ditches

Large ditches and canals, 15 feet wide or more, and miles in length, often justify the use of a floating dredge. Those who are interested in methods of trenching for underdrains, and in excavating machinery, floating dredges, ditching plows and the like, should get Farmers' Bulletin 698 of the U. S. Department of Agriculture. It goes into the subject in detail.

An entirely successful ditch blasted through heavy, thick muck. Note that the watertable is very near the surface of the ground. The soil is not thin enough to cave in or float into the excavation, hence the blasting is at its best. (In Howachitto Swamps, Adams Co., Miss.)



What can be done by blasting in sand. This big ditch was made with explosives near Pinellas, Florida. The conditions are about the most unfavorable under which it is possible to blast out ditches. Heavy charging and electric firing were required here.

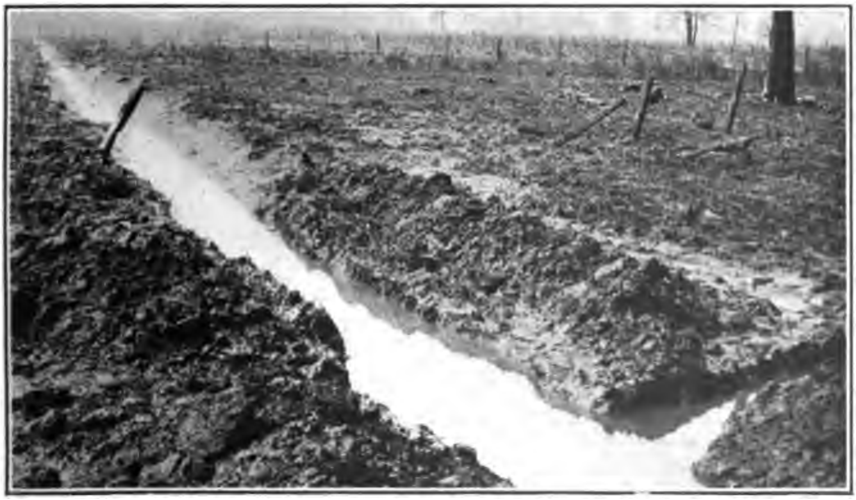
When many stones, roots and stumps are present, a dredge, or in fact any excavating machinery, cannot be used to advantage or at all. Ditches less than 2 feet deep can be plowed out cheaply, using two or four horses hitched by means of a chain to a plow of some kind. Another implement that is effective for making very shallow ditches is a scraper, either with or without wheels. A road machine or scraper is about as good as any. The trouble with them is that they will work little more than to a depth of a foot. They also are expensive. Their advantages are that they scrape the dirt well back from the edge of the ditches and make an even, clean-looking job by machinery instead of by hand.

When tile is to be laid in hand-dug trenches, begin the spade work in the bottom of a plow furrow. By running the plow twice in the same place you can make the furrow nearly 12 inches deep.

Blasting of ditches is discussed under a separate heading.

Possibilities and Limits of Blasting

The blasting method can be used for making almost any open ditches. A blasted ditch made with one line of charges usually is about twice as wide



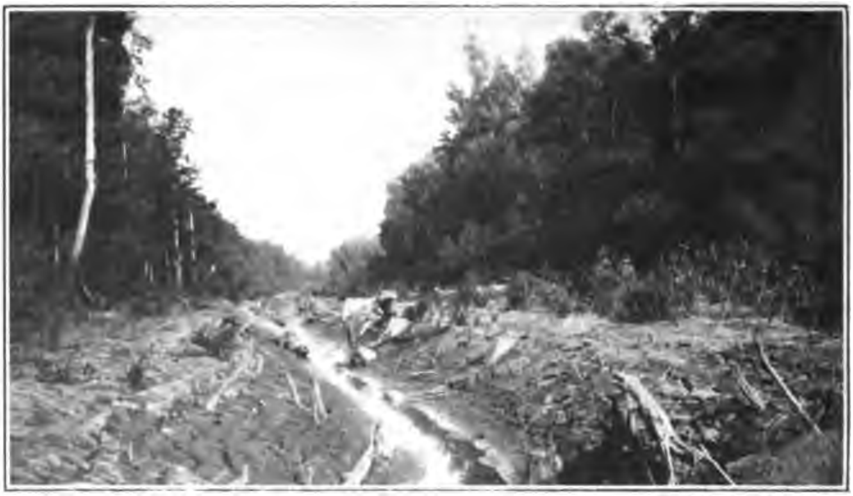
Blasting makes the cleanest and smoothest job in sandy loam that is saturated with water nearly to the surface. Note how cleanly the edges of this ditch are cut. Also note that no excavated earth was thrown to the right of the ditch, in the picture. A strong wind carried it all over to the left side.

at the top as it is deep. The sides and bottom are fairly even. The dirt is spread out widely without leaving ridges down the sides. Ditches can be blasted successfully in clay, loams, gravel, thick muck, peat, and, in fact, every sort of earth except very thin muck and dry sand. Ditches can be blasted through sand when saturated with water.

It is easier to state the limitations of the blasting method than its possibilities. As stated above, you cannot blast ditches through dry sand. Thin muck runs into the excavated channels. In any ground where there are many roots of trees or brush, the sides of the blasted ditch will be ragged unless the roots are cut beforehand along the sides. In blasting through heavy sod, the sod sometimes folds back without tearing loose, or else simply flops back down into the ditch—unless the edges are cut before the blast.

These are the limitations of blasting, and there is a way to overcome each of them except that of thin muck. The fact is that the way explosives will cut out a narrow channel is really wonderful. Those who have not seen the blasting of a ditch can have no idea of the efficiency of the work of explosives for this purpose or of the clean and finished job they do.

Explosives work to the best advantage when the ground is wet—in fact in thin mud. It takes less explosive to throw out a required sized ditch, or the same amount of explosive will make a bigger ditch, when the ground is thoroughly wet than when it is only damp or is dry. The blasting may be done with perfect satisfaction through ground that is so soft that there is no footing for horses and no support for wheels. In fact, it can be done when the surface of the ground is under water.



A big ditch blasted through a swamp where the muck was almost too thin. The sides of the ditch moved in a little, but stopped as the water left them and they dried a little. Blasting is very effective in muck, so long as the material is not so thin that it moves in and closes the excavation later. (Gilliard's Lake outlet to Mississippi River, through Howachitto Swamp, Adams Co., Miss.)

Excessively soft ground, stones, stumps and roots are the things that make ditching by hand or by machinery costly and difficult, if not impossible. But they interfere with blasting very little and raise the cost only slightly. Blasting of ditches can be done in dry ground of a heavy nature. The general rule is that the wetter the soil, down to the thin muck stage, the better and cheaper the blasted ditch.

The cost of digging by hand in connection with plowing and scraping, in any ditches more than 2 feet deep, is upwards of 25 cents per cubic yard, on a basis of $1.50 per day labor. The cost of blasting will range from 6 to 16 cents per cubic yard, depending on the nature of the soil, its condition at the time and the skill of the blaster. This comparison in itself is enough to demonstrate the efficiency of the blasting method.

It is possible to blast out a good ditch through almost pure sand, as this ditch shows, provided the ground is full of water and the operator understands his business well.

About the smallest ditch it is worth while to blast is 1½ feet deep and 3½ feet wide. From this size up to 6 or 8 feet deep and 18 or more feet wide the use of explosives has advantages over almost any other method under favorable conditions. But in general the efficiency of the blasting method falls off after the depth is greater than 6 feet and the width greater than 18 feet. For long ditches a floating dredge will be economical. Small ponds may be dug by blasting.

In blasting ditches two or three men can do the work of a great many. They can accomplish in a day or two what would take them months to do by hand.

Laying Out the Ditch

The size or capacity of ditch required, the grades, the depth and the lines should receive careful attention. When there is considerable length of ditch or considerable acreage to be drained it is wise to employ a drainage engineer or a professional surveyor in getting the grades and in determining capacity. Except in very large operations the matter of depth and location of the lines of drains is largely one for farmers themselves to decide, because they know the requirements of the different soils and of farm operations, as well as have had the chance of observing the flow of flood water.

The eye is not to be depended on in determining the fall of a piece of land that is nearly flat. Use a level. One way of using it is to drive a post at the upper side and fasten to this, by nailing or bolting, a crosspiece with a straight edge up. Then lay a level on the straight edge and make it absolutely level. The crosspiece should point directly toward the lower side of the piece of land

In big drainage projects where large canals must be made the blasting method often proves economical. There is no doubt that explosives will do the excavating, as this picture shows. Labor cost and complications are reduced to a minimum on account of the few men and short time requires for the blasting.

to be drained, where a helper must stand, holding a marker which he raises or lowers on a pole. Sight over the straight edge and have him elevate the marker till it is on a true level with your crosspiece. The difference between your distance down to normal ground surface or normal water surface, and his, will be the fall.

An "A" frame or any other support for the level will do if it will hold the level steady. For about 60 cents, sights for attaching to the level can be bought of almost any hardware store. Ask for Stanley level sights. They are as accurate as rifle sights. Tripods for holding the level also are made by the Stanley

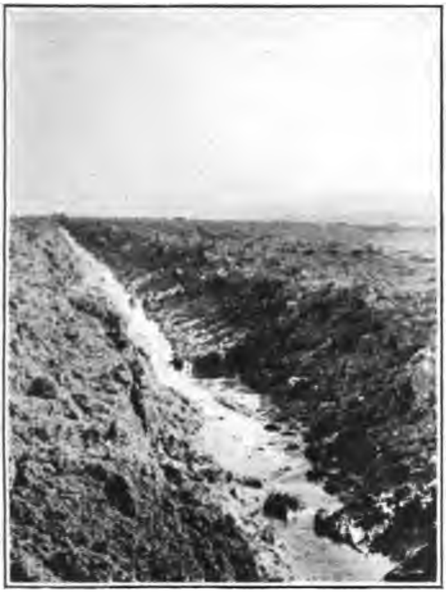
This ditch is a good instance of the speed and efficiency of the blasting of ditches. Three men made it complete, as the picture shows—1000 feet long—in 5 days. About 400 pounds of explosive was used. Much cutting of roots and sod was required. (The Hart E. Hutchens Co., New Britain, Conn.)

firm and cost about $2.50 at most hardware stores. The plain level is not very accurate. If you do not use sights, repeat the sighting two or three times to make certain of the finding.

Another reliable way of getting a grade is to use water in a hose. Use a length of 20 to 50 feet of hose. Turn up the ends for 6 or 8 inches and tie them up. It is well to insert in these ends, tubes of glass, like the water-gauge glass of steam engines. Fill the hose with water and lay it on the ground or in bottom of ditch. The height of water in the ends will show the level. You can use this device round bends in a ditch.

Grade, Fall and Line of Ditch

A fall of one inch to each hundred feet is enough to carry off excess water from a field in most cases. This is for straight ditches. If the ditch line is to swing here and there, an inch of fall is hardly a sufficient allowance.



Part of a half mile of ditch blasted out complete, with no work in preparation or finishing ground. The ground was full of water, and transmitted detonation was made use of to fire the charges in about 200-foot sections. Note that the line of the ditch is true, the edges fairly even and smooth, and the earth well scattered.

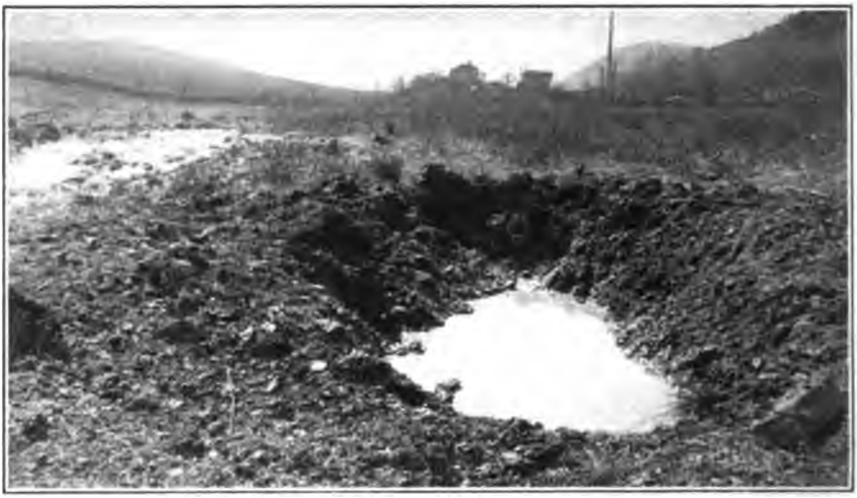
The appearance of grade is deceiving. Few pieces of ground are so flat they cannot be drained. Watch the land when it is flooded and the water is going down. Set some stakes then to indicate its level and its channels. If a small stream flows through the land, the line of sight should not follow its wandering course. The total fall should be determined from just two positions—one where the stream enters and one where it leaves.

The flow of the flood water is a good guide in locating the proper line for a ditch. This is the natural line of drainage. If nothing else interferes, place the ditch in this position. The idea is to have it near as possible to a straight line and as short as possible. But avoid cutting fields with open ditches when possible.

Determining Ditch Depth

The one important factor to consider in determining how deep a ditch should be is the proper height of the water-table in the ground. This is the level of the water that will stand in a well or hole dug in the wettest part of the field. The water should be at least 4 or 5 feet below the surface in ordinary heavy loam or clay, and 1 to 1½ feet in muck.

The deeper a ditch is the farther and more thoroughly it will drain land. Your calculations as to how far you can rely on one ditch to gather water and to effect the drainage of ground must be based on this matter of the depth of the ditch. The nature of the ground has a good deal to do with it, particularly with the rapidity of the drainage. A loose, open gravel will drain out nicely in a few days, and a tight stiff clay will take



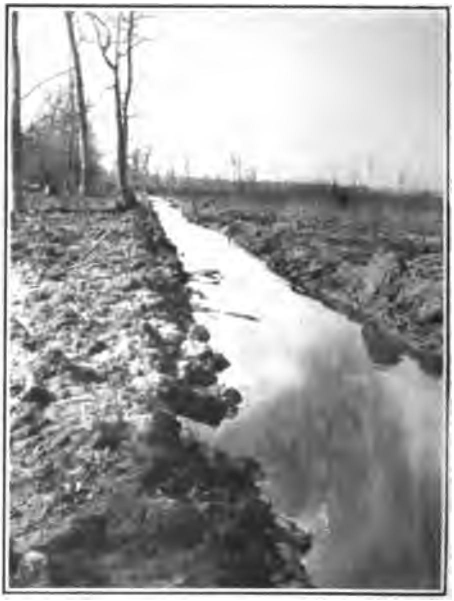
The first shot (of 12 charges) of a ditching operation. Note particularly how abrupt and clean-cut the end is. The last charge lifted its load fully and cleaned out the ditch in good shape. The next one placed beyond will continue the excavation just as well. (Mud Lick Farm, Julian, Center Co., Pa.)

weeks. Naturally the ditches should be closer together in the clay than in the gravel. Other soils can be judged from these.

The depth must not be more than the water-level at the mouth of the ditch or drain. This is a governing factor in many places. When a ditch empties in a stream you often can carry the channel farther down and secure a lower level if it is needed; or the stream itself may be deepened.

Determining Width of Ditch

The water carrying capacity of a ditch is most largely governed by its width. Often the narrowest ditch that can be made will have more capacity than is needed to carry all the water there is. The bottom should not be wide, but should be narrow, almost like a broad V, because the amount of water to be carried at low water stage is small and it should be confined closer to make it flow better. In flood times the water will rise higher and will make a broader stream.



This ditch is 5 feet wide and 3 feet deep. It was blasted out with one row of charges placed 18 inches apart, each charge consisting of one stick of powder. About 100 feet of the ditch was excavated at each explosion.

Where large swamps are to be drained, or the flow from larger springs is to be carried away, a ditch of minimum width sometimes is not big enough. If you can calculate the volume of water to be carried away, you then can figure the correct width for your ditch. Measure the flow per minute in cubic feet at some outlet. Or measure the amount of standing water by getting its depth and extent. Provide ditch enough to pass the volume present in the required time. In any case the ditch should be big enough to clear away the water of a 2 or 3 days' rain shortly after it stops coming down, and to take care of spring floods.

How to Make Ditches by Blasting

Description of Blasted Ditch

Ditches are blasted by loading suitable charges in holes made in a row or line. Each charge of explosive properly placed for ditch blasting will blow out, roughly stated, a crater which is half to three-quarters as deep as it is wide. Nearly all the dirt is thrown out. Most of it is lifted to a height of about 200 feet in the air, requiring some seconds before it returns to the ground.

The sides and bottom of blasted ditches have 6 to 12 inches of loose dirt, which can be left where it is if the ditch is big enough in the clear, or can be taken out easily and cheaply by shoveling or

In these ditches the excavation of earth was satisfactory, but the number of roots was so great that the result as a whole is not what it should be. No side-cutting was done before blasting. If there had been, the resulting ditch would have been smooth, straight and deep. In blasting through brush and timber, the long, sharp shovel blade, the hay-knife and the axe are necessary tools. (S. Chester Coursey, Hayden, Md.)

with light horse scrapers if a larger ditch is wanted. Good blasting practice will so load the charges that the ditch as cleaned out by the blast will be big enough in the clear and will require very little, if any, hand finishing.

Firing Charges

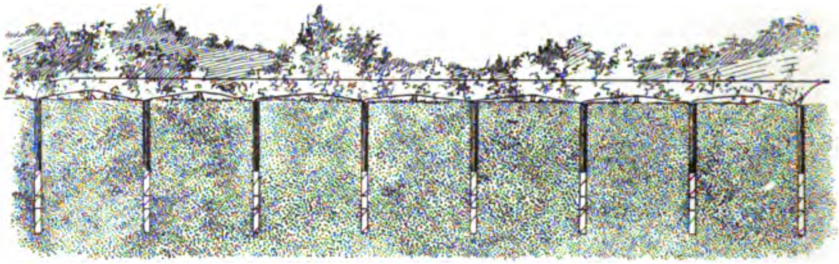
One of the first things that must be considered when planning to make a ditch by blasting is the method of firing the charges of explosive. Most of the rest of the operation hinges on the firing so much that this matter must be determined before even buying the explosive.

The standard practice is to fire all charges electrically, as will be described immediately following. This method is sure in results under any conditions. Ordinary cap-and-fuse firing cannot be used successfully in ditching, except by the transmitted detonation method in which the center charge only is set off by a cap, the rest being fired by shock transmitted through the ground. This method is fully explained on pages 22 to 25.

General Method of Firing

Ditches can be blasted through any sort of ground except dry sand when the charges are fired in this way. The procedure is as follows:

The charges are prepared for loading, with electric blasting caps, in the manner described on pages 34 to 38. Prime each charge. Holes are made in the ground on the ditch line and the charges are loaded as described in following pages.



Typical loading of ditch blast for straight electrical firing of all charges for 3½′ x 7′ ditch.

The holes or charges should be spaced 30 to 40 inches, and where very heavy charges are used, as much as 50 or 60 inches apart. They must be close enough together so that all the earth between each two will be thrown out clean, leaving no ridges in the bottom of ditch. Thirty inches ought to be close enough under any conditions of soil and size of charge. The only way of determining definitely just how far apart the charges should be is to make test shots, as suggested on page 31, in the discussion of amount of explosive required for charges. As many charges should be loaded as your electric current can fire.

The actual firing is done by connecting the wires of all the charges and sending an electric current through them. An electric blasting machine should be used to supply current, though power or light current can be used. A full discussion of the details of how to connect wires and to fire, is contained in the special chapter on the subject in the latter part of this bulletin.

You can fire as many charges as your blasting machine will handle. The machines are made in different sizes, to fire 3 to 150 charges at once. Procure a large machine if you have miles of ditch to blast, but if you have only a few hundred yards, a 30-charge machine is big enough.

The proper explosive for blasting ditches by this method depends somewhat on the soil. In all clay and heavy soils use 20% ammonia powder or dynamite, and for large ditches use 30% or 40% ammonia powder or dynamite except when the work is under water. (See page 46.) In blasting ditches in wet sand or other light ground use 50% nitroglycerin dynamite or powder. Where charges must remain under water more than half an hour, use nitroglycerin explosives only, for ammonia explosives will deteriorate if soaked for excessive periods of time. It is well to use a low-freezing grade of the explosive at any time of the year, since this guards against incidental chilling, and since the cap is strong enough to detonate all grades fully.

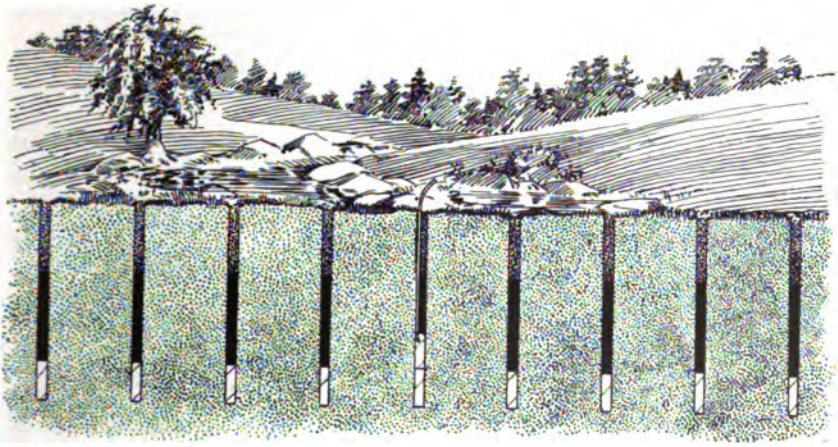
Electric blasting caps, connecting wire, leading wire and blasting machine with the other tools needed for loading, are the supplies demanded for ditch blasting by this method.

Depth for holes, amount of explosive per charge and many other details of the loading are discussed on pages 28 and 30.

Transmitted Firing

When the ditch is to be blasted through ground that is saturated with water, the method of transmitted firing often can be used to advantage. In order to insure its complete and unquestioned success, the water must cover the charges and had better rise in the holes nearly to the surface of the ground.

Under such conditions transmitted detonation can be expected to succeed even in sandy ground and gravel. It is in muck and clay fully saturated with water that the method is most successful.



Showing typical loading of transmitted detonation ditch blast—fuse firing—for 3½′ x 7′ ditch.

Transmitted firing is made possible by the fact that high explosives can be fired by shock (as by that given by a cap, for instance). Under the conditions of soil described above and of proper loading, the shock of the explosion of one charge will travel through the ground and water with enough force to fire the next charge, and so on down the line. So rapidly does this take place that in a line of charges hundreds of feet long you cannot see any difference in time between the middle and end explosions.

If sticks of explosive are laid on a plank a foot apart and one of them is fired with a cap and fuse or otherwise, the others likely will be exploded by the influence projected through the air. In actual ditching work the shock of one charge cannot be depended on to travel through the ground strongly enough to bring about full and complete detonation more than a couple of feet.

The usual distance apart that is best for charges to be fired by transmitted detonation is 15 to 20 inches. The exact distance in any particular soil at any time must be determined by test shots. Try a shot of 8 or 10 charges, (of the amount of powder and at the depth of loading required, as explained on pages 30 and 31) spaced 12, 15, 18, 20, 22, and 26 inches apart.

Spacing of Charges

Careful observation of the blast resulting will show the point beyond which charges fail to explode or explode weakly. The correct spacing of charges, to insure full detonation, will be about two-thirds of this limit.

One charge may fire another at a greater distance than is economical, because it merely may explode it weakly, without developing anything like the full force and speed. And on top of that, each weaker explosion sends a still weaker one on to the next charge, till a point is reached a few charges away where the shock transmitted is not enough to bring about firing at all.

This weakening of the transmitted shock is important, because the strength of an explosion of powder or dynamite depends on the severity of the shock which fires it. For illustration, and not that these figures bear any relation to the true amount of force, if the first charge, the one fired with a cap, gives off 10 pounds of energy in the form of a shock, and this 10 pounds is diminished to 8 pounds by the time it reaches the next charge, this second charge will not detonate with quite 10 pounds of shock energy. It may have only 9 or 8. And in turn, the shock energy from it will be diminished to 6 or 7 on reaching the third charge. If the particular kind of explosive used requires a full 6 pounds of shock to detonate it completely, the transmitted method of firing is going to fail. Even of those charges which do explode, half will give much less than their full force.

Water is not elastic, but air is, and dry soil is and absorbs shock because it contains a good deal of air. The gases of an explosion drive water-soaked

When roots and sod are not cut along the sides of the ditch before the blasting, the edges are never as smooth and as straight as with cutting. An effort was made to trim this ditch up after the blast. It carries water about as well, but it doesn't look to be as good. (In Miller Drainage District, Marion Co., Oregon.)

ground as a steel rod can be driven by a hammer. In it there is but little "give," hence the shock travels with a minimum of loss in force. In dry ground the air cushions the blow of the gases and eases them to a standstill within a short distance. Clay is more solid than sand, which fact explains why transmitted detonation works better in heavy soils than in light ones.

The nature of the ground and the amount of water present therefore largely govern the spacing of charges, though a large charge of course will throw a shock slightly farther than a small one.

As will be seen from foregoing named facts, the effects of lack of water and of light, spongy or sandy ground, can be counteracted somewhat by setting charges closer together. When necessary it is practicable to put them only a foot apart. To put them closer, however, is not practicable, for it costs too much. On the other hand, when the charges are heavier than ordinary—say of two sticks or more—in wet, heavy ground, they may be spaced up to 26 inches apart with satisfaction.

Temperature of Ground

Temperature influences transmitted detonation only by reason of the fact that explosives are less sensitive to shock, and harder to fire when cold than when warm. All grades explode easiest when at a temperature of 70 to 80 degrees. Straight nitroglycerin powder or dynamite must be used at a temperature of higher than 50 degrees. It is not well, for many reasons, to attempt to fire too many charges at once. Several hundred can be fired successfully sometimes, but the usual limit had better be 50 to 100.

When the nature of the ground, amount of water present or temperature are not of the best for securing transmitted detonation, sometimes matters may be helped by taking advantage of the fact that blasting caps are much more sensitive to shock than the explosive itself. Place a common blasting cap, without a fuse. but with the open end filled with tallow, every 25 to 50 feet. These caps may help to restore the diminished force of explosion, making satisfactory detonation extend much farther than it would without them.

A ditch 10 feet wide and 5 feet deep through newly cleared land. The extra width of the excavation helped to tear entirely loose and throw out stumps and roots, leaving the edges comparatively clean of projecting roots. Under such conditions finishing the ditch after blasting is better than to try to cut the edges before. (Paragould, Ark.)

Stones, roots and old logs interfere with transmitted detonation. When these are located in the line of the ditch it is necessary to fire charges on both sides of them as at the beginning. Pay careful attention to changes in soil as you work along the ditch line. It may be necessary to shorten the spacing, or, again, it may be possible to lengthen it and save money.

Prime Center Charge

The firing of the line of charges by the transmitted detonaticn method is done by loading the required number of charges without priming or with caps and no fuse as described above, all except the center charge of the row. In it place a double charge of explosive, or at least an extra stick of explosive, primed with cap and fuse or with electric blasting cap. Fire this charge in the usual way.

Sometimes an electric blasting cap placed at each end as well as at the middle of the line will fire difficult charges successfully. Once in a while the electric blasting caps may be needed even closer—say every 3 to 5 charges.

The Explosive to Use

The proper explosive for transmitted firing ditch blasting is nitroglycerin dynamite or powder of 50% strength —either regular or low-freezing. The 20% strength dynamites and powders recommended for electrical firing cannot be used at all under this method, because they are not sensitive enough.

Summary of Firing Facts

Transmitted firing requires only the explosive itself, and a cap and some fuse for each couple of hundred feet of ditch, while electrical firing requires wiring, an electric blasting cap for each charge and a blasting machine or other source of current. This advantage of the former method very often is offset, however, by the fact that it requires nearly twice as many holes as electric firing. It is easier to load two sticks in one hole than to make two holes. In addition, electric firing always can be depended on for the desired results, while transmitted firing will succeed only when the ground is full of water. As for quantity of explosive required by each method to excavate any certain ditch where either can be used: In theory the two methods require about the same. In practice, however, more will be used in transmitted firing, unless the work is done very skillfully. The saving in the use of this method comes largely from a saving of electric blasting caps and time, and the need for little equipment.

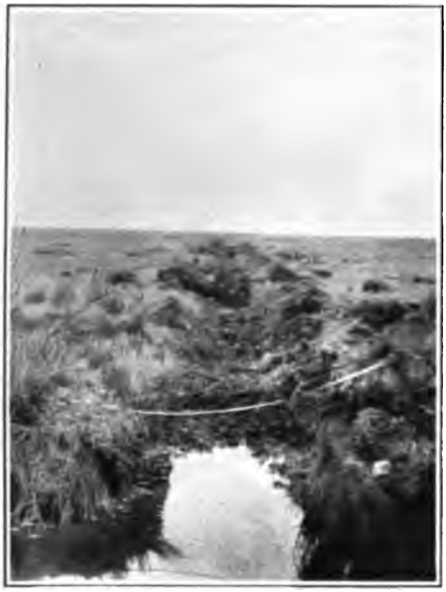
Preparation of Ground and Loading

Cutting Roots and Sod

During the early days of ditch blasting, before experiments had standardized practices, much objection was taken to the ragged edges of ditches blasted through sod and through brush and woods. The sod would not tear loose and fly away from the ditch. It would either fold back and make a ridge along the ditch, or it would flop back into the ditch after the dirt beneath had blown out. The remedy is to cut the sod and roots along the edges of ditch before blasting.

When there is sod, two furrows should be plowed along the ditch line—one at each edge. Another plan is to cut along the sides of the ditch-to-be with a spade, axe or hay knife. In case the line of the ditch runs past trees, or through brush or forest land, the roots should be cut on both sides the ditch. An axe is needed for the big roots. Where there are many roots the ground should be cut 18 inches deep.

Make the cut at the angle the side of the ditch should have, say about 45 degrees. The blast will clean out the dirt to the cuts and will leave the wall on the outside firm and intact. Cutting the edges of the ditch saves trouble and work after blasting. It insures that the sides and edges of the ditch will be as straight as though the ditch was shoveled by hand or plowed. But it should not be understood that ditches cannot be blasted without cutting the ground. Except through extremely heavy sod and roots, explosives used alone will clean out good channels when loading and firing are done properly. The cutting of the edges simply makes a smoother, more complete job.



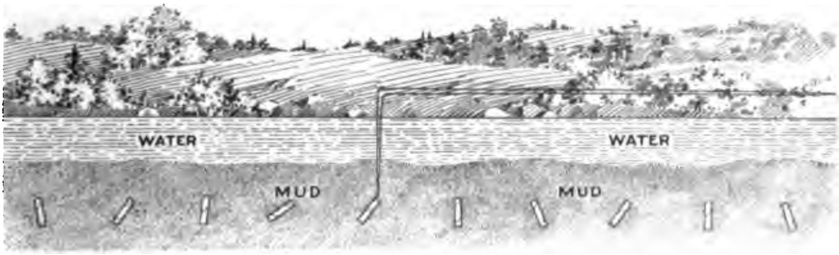
A typical instance of what results from an attempt to blast a ditch through heavy sod without first cutting the sides. The sod breaks loose in the middle of the ditch and either folds back without tearing loose or falls back into the ditch after the dirt beneath it has been swept away. Such ground should be thoroughly watersoaked and the edges of the ditch cut with shovels or hay-knife, or at least by plowing furrows. (Virginia.)

Locating Line For Holes

The charges should be placed along the center line of the proposed ditch, except where the ground is harder, or higher at one side than at the other, when they should be placed 6 to 12 inches from the center toward that side. The eye is not capable of keeping the line of charges true. Stretch a string where they should go. In making the holes the man should have a measuring stick to space them accurately. Guesswork on this point is likely to be expensive.

Make the holes straight down into the ground. The practice used to be to make them at a 45 degrees slant, but this offers no advantage in any way.

It is much easier to make holes in soggy ground than in dry ground. In fact, it is almost impossible to sledge down a bar in some dry ground. When there are no stones, a soil auger often is of advantage, though the bar and sledge are hard to beat for speed and results. The only modification of the up-and-down position of the sticks or charges that is desirable is when you are deepening ditches already made, with bottoms of thin mud or thick muck. In such material you need punch no holes. Just push the sticks into place down in the mud with your hand and place them in a horizontal position lengthways of the ditch.



Typical loading for deepening ditch with bottom of mud—electrical firing of center charge for transmitted detonation.

An explosion throws the earth so high that the slight additional depth or height of sides met with in deepening a ditch does not interfere materially with the excavating action of the blast. Probably a little dirt is caught and rolled back by the side walls, but the percentage of the total lifted is small.

Preventing Dirt Falling into Ditch

If you have a windy day for the blasting, with the air drawing strongly across the line of the ditch, you will be surprised to see how far the falling dirt will be carried away from the ditch during the few seconds it is in the air. On a quiet day, 6 to 12 inches of dirt will fall back into the ditch. On a windy day your finished ditch will be several inches deeper and wider than on a calm day. Do not take from this that a windy day is demanded for satisfactory results. The force of the blast spreads and scatters all but a little of the dirt. The wind merely helps.

When water covers the charges, be sure to make the primed sticks, and the cap and fuse, waterproof with tallow or paraffine at points where they join. Shoemaker's wax is another good thing, but is expensive. Tar and thin lubricating grease are very poor materials for waterproofing.

Waterproofing Charges

When water covers the charges you should arrange to load them and to fire them quickly. A good plan is to make all the holes for one section, then prepare the charges, as to priming and waterproofing and distributing them along the line. Quickly test each hole for fallen stones, caved-in dirt, and push the charges to the bottoms of the holes. It is best to limit their soaking to a half hour. The explosive is likely to weaken if left too long.

If the holes cave in soon after the bar is withdrawn, do not attempt to load and blast long sections at a time. In loose gravel and sand, especially where water cover the surface or nearly so, you will have trouble getting the charges down to the bottoms of holes. The best plan is to get a tin tube about 1½ inches in diameter and sink it in the hole over the bar. The explosive then can be loaded without trouble when the bar is withdrawn.

Tamping Ditch Charges

Generally speaking, a ditch charge should be tamped slightly. The more tamping you use the broader your ditch will be in proportion to its depth. If you want a narrow ditch you must let the gases rip their way upward easily. In dry or damp ground, fill the hole about half full and tamp well. When water rises high in the hole, use no tamping at all, except to tramp shut the upper 6 inches.

The ground had better be warm for ditch blasting. If it is cold you must load and fire the charges quickly, to prevent chilling of the explosive. A light crust of frozen ground makes little difference when charges are handled properly; more than ¼ to ½ inch will interfere seriously.

Regulating Depth and Width

Depth for Charges

The dirt will clean out 6 to 8 inches deeper than the bottom end of the charges when conditions are normal. Explosives work more efficiently in ditch blasting when they are placed as shallow as possible. When the holes are too deep an excessive amount of explosive is required. A layer of hardpan or cemented gravel in the ground to be removed requires slightly deeper placing than soft ground. The rule for the usual job is to place the charges within 6 inches of the bottom depth desired, and for large ditches and heavy charges within 10 or 12 inches of the desired depth. The exact depth may be ascertained by trial shots.

The greatest depth it is practicable to blast at one shot is about 6 feet. If a deeper ditch is wanted, blast a second time in the bottom of the first excavation. (See table on page 31 for depths for charges.) The blasting out of very large canals should proceed along these lines. They involve no principles not explained for the making of small ditches.

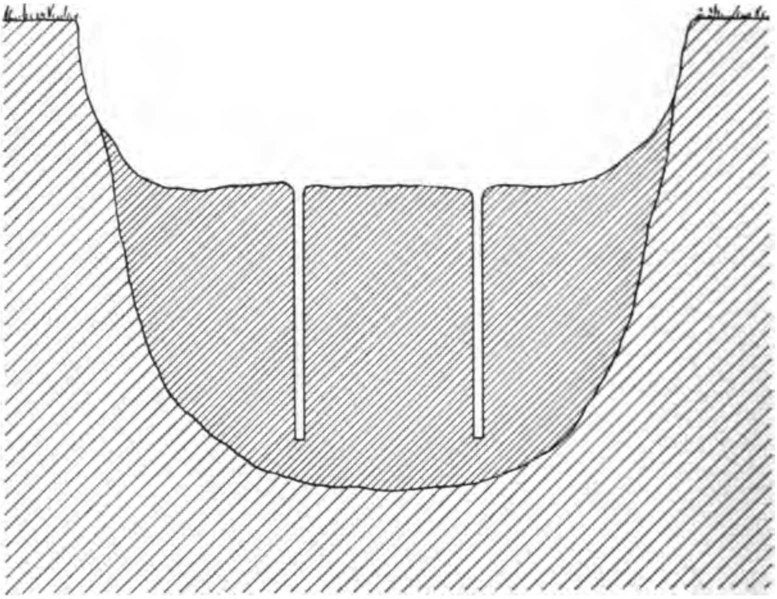
A channel 35 feet wide and 6 feet deep that was excavated by blasting. The water has smoothed the sides a little, but in the main the big ditch looks in the picture as it looked after the blast which opened it. The cost of such ditching can be figured accurately in advance when dimensions are known, the kind of soil and its condition considered, and the cost of explosions at hand. (Athens, Ga.)

One line or row of charges frequently will make a ditch up to 12 feet wide and 6 feet deep. To make wider ditches use 2 or more rows.

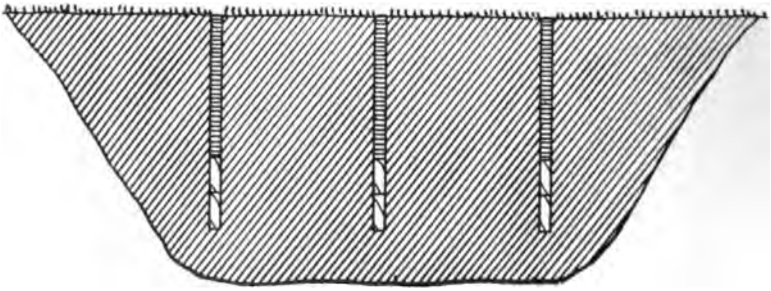
Wide Ditches

Usually 2 rows of charges will be needed for ditches between 8 and 12 feet wide if less than 4 to 6 feet deep, and 3 rows for ditches 12 to 18 feet wide.

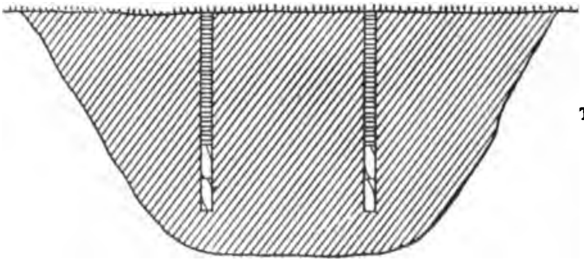
The lines or rows of charges should be placed about 4 feet apart, except where the charges consist of more than 4 sticks and are close together in the rows on account of transmitted detonation, when the rows may be as much as 6 feet apart. In blasting out very wide and shallow ditches or canals, it sometimes is of advantage to load 2 rows with light charges rather than to attempt to blast out



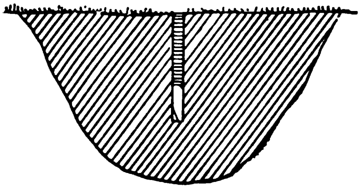
How to deepen ditch by a second blast in the bottom of a first excavation.



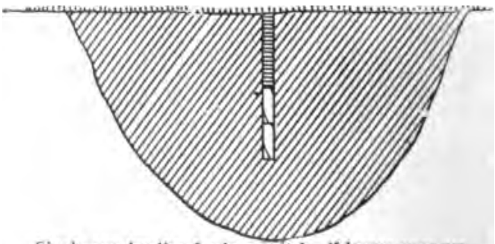
Three-row ditch loading—See page 28.



Two-row ditch blast loading.



Half stick loading for very small ditch.



Single-row loading for large ditch—if larger ones are needed, more rows of charges.

the ditch to the required width with one row heavily loaded. The heavy charges might dig deeper than required. (See table on page 31).

Invariably all the rows should be fired together. This, of course, is accomplished when the electric method of firing is used. When using the transmitted detonation method, put in extra charges between the rows at the center charges, and then fire one—usually the center charge of the middle row—with a cap and fuse. All these center charges and extra charges should be *heavier than usual.* Put in an extra stick, at least. A still better way with transmitted detonation is to fire the center charges of all the rows together electrically.

A pond excavated entirely by blasting. Several rows of charges were loaded and fired simultaneously. The wind carried the earth to one side, forcing it to fall on adjoining ground instead of back into the hole blown out. (H. E. Ellis, Ashland, N. J.)

Amount of Explosive Required

Before giving tables of the average amount of explosive required for various sized ditches, it is well to describe a few typical examples of ditches that have been blasted, of which records were kept.

Examples

In a clay soil, with water rising almost to the surface of the ground in the holes punched for charges, charges of one stick of straight nitroglycerin explosive placed 18 inches apart and 30 inches deep blew out a ditch 4 feet deep, 3 feet wide at the bottom and 7 feet wide at the top.

In a similar soil, with less gravel, charges of one-half stick of straight nitroglycerin explosive placed 15 inches apart and 18 inches deep made a ditch 2½ feet deep and 5 feet wide. At another point in the same field, on the same day, charges of 2 sticks (one pound of same explosive), placed 30 inches deep and 24 inches apart, made a ditch 9 feet wide and 4 feet deep.

In loam ground, too dry for successful transmitted detonation but still somewhat damp, charges of 2½ sticks placed 2½ feet deep and 3 feet apart, and fired electrically, cut a ditch 4 feet deep, 8 feet wide at the top and 2 feet wide at the bottom.

Through a thicket with brush and small trees measuring 1 to 3 inches in diameter, in heavy pure loam well soaked with water, charges of 2 sticks of straight nitroglycerin dynamite placed 22 inches apart and 3 to 3½ feet deep made a ditch 4 feet wide at the bottom. The ditch was loaded too heavy. Charges of 1½ sticks would have been better.

In very wet and miry clay, a ditch 20 feet wide at the top, 12 feet wide at the bottom and 6 feet deep was blasted with 3 rows of charges of straight nitroglycerin explosive. All the charges were spaced 20 inches apart in the rows. The charges in the middle row were 1½ to 1¼ sticks, varying a little on account of variations in the soil along the ditch. In the two outside rows the charges were one stick each. The rows were placed 4 feet apart. One section of the same ditch was cut out to a depth of nearly 8 feet by using 1½ sticks to the charge in the 2 outside rows, and 3 sticks to the charge in the middle row.

Amount Excavated By One Pound of Explosives

When the ground is fairly heavy and is full of water you can count on each pound of explosive properly placed to clean out 1½ to 2 cubic yards of earth. The variations from this rule, both ways, will be on account of the presence or absence of water, the nature of the soil and the size of the ditch. A ditch made with a single line of charges (measuring, usually, 3 to 4 feet deep by 3 feet wide at bottom and 6 to 7 feet wide at top), will give the highest efficiency, and when the conditions are very favorable will show even a little more than 2 cubic yards per pound of explosive used.

As the amount of excavation in one body increases, the efficiency of each pound of explosive will fall off somewhat. In very large ditches that are wet you will get out only 1½ cubic yards per pound of powder. In dry ground blasting, particularly if the ground is light, 1¼ or even one cubic yard per pound will be the average.

Number of Half-Pound Sticks of Explosive Required per Charge for Blasting Ditches

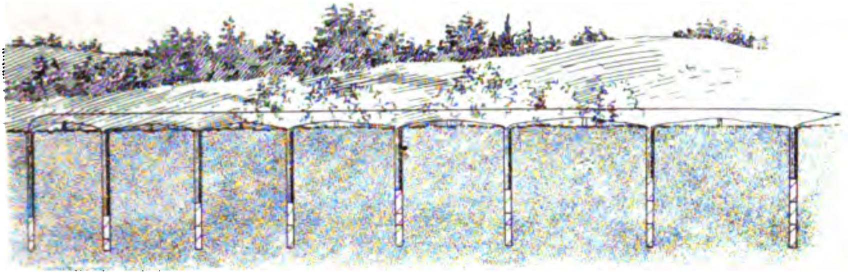
Depth Ditch	Depth Hole	Amount Charge Transmitted Detonation	Amount Charge Electric Firing
2 ft.	1½ ft.	½ stick	½ stick
2½ ft.	2 ft.	¾ stick	1 stick
3 ft.	2½ ft.	1 stick	1¼ sticks
4 ft.	3¼ ft.	1½ sticks	2½ sticks
5 ft.	4¼ ft.	2 sticks	3½ sticks
6 ft.	5 ft.	2½ sticks	5 sticks

The width of the ditch can be calculated by doubling the figure for the depth in case of a single row of charges, or in the case of more than one row, by adding to the figure for double the depth the distance between the rows of charges.

The table given above is correct for average conditions. Since variations in soils, temperature and other factors make necessary varying loading, the figures here should be used as a guide for starting test shots.

Making Test Loadings

No ditches should be blasted without testing the loading thoroughly before proceeding with much work. Blast small sections at a time, and vary the loading to suit the changes in the nature and condition of the ground you encounter along the ditch line. Clay, sand, muck, loam and gravel all require variations in depth of charge, amount of explosive and sometimes in spacing of charges. Proper tests will enable you to decrease the cost and to make a better ditch than otherwise would be possible.



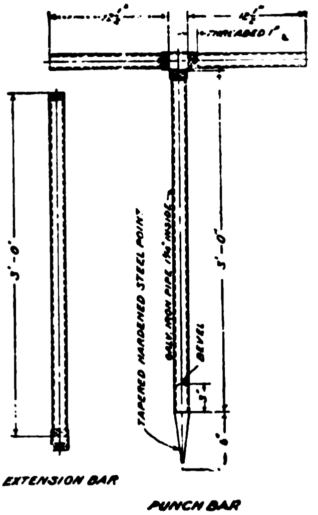
Typical test loading to determine proper charges and placing of explosives for electrical firing. Note the variations in spacing between holes as well as in amount of explosives used. (See page 23.)

Five to ten holes make a good test. This should be repeated several times. Vary the depth and spacing and the amount of charges. *Remember that proper blasting will make perfect ditches at low cost, and that the only final way of determining proper loading is to try it.* Well-balanced charges will be so loaded and spaced that the gases will lift the full load of dirt without overlapping much and without skipping any ground between. Load just heavy enough to insure clean excavation without excessively high throwing of dirt.

Time Required

Making 3-foot holes in clay and gravel, preparing charges, loading and firing can be done by one man at the rate of 20 to 50 charges per hour. If there are many stones in the ground, or if the ground is hard, the work will go slower. Wet gravel makes slow work. Two or more men will get more done in proportion than one man. Under favorable conditions one man has blasted out 1,000 feet of ditch 3 feet deep in 12 hours. One man should be able to blast 350 to 450 feet of ditch per day through brushy ground; if the land is clean he can do more, though where ground is so dry as to cause trouble in making holes, the work will go slowly.

A crew of ten men—eight laborers, one blaster and a boss—working at a big ditch. The employment of so many men is not justified except for very long ditches, for the job lasts only a day or two. A good sized crew enables the blaster to place and to fire the charges quickly, which is an advantage when the holes fill with water and when the temperature is low. (Max Ostner, Diehlstadt, Mo.)



EXTENSION BAR

PUNCH BAR

How to use pipe to make a punch bar or to extend an auger.

Tools Required

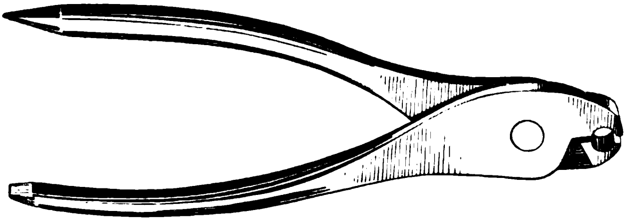
Ditch blasters should have a soil auger, two crowbars, a sledge, a couple of long-handled shovels and a cutting spade. One of the bars should be 4 or 5 feet long and should be constructed for driving. The other should be 6 or 7 feet long, and may be made of piping, with a solid sharp steel point welded in. It is for use as a churn drill, without sledging. A broomstick or a wooden rod about 1½ inches in diameter, for pushing the charges down and tamping, and an axe to help cut roots, also are handy. Of course, boxes or baskets for carrying explosives, cap crimpers and the usual outfit for handling and loading explosives as described on pages 36 and 37, will be required.

Incidentals

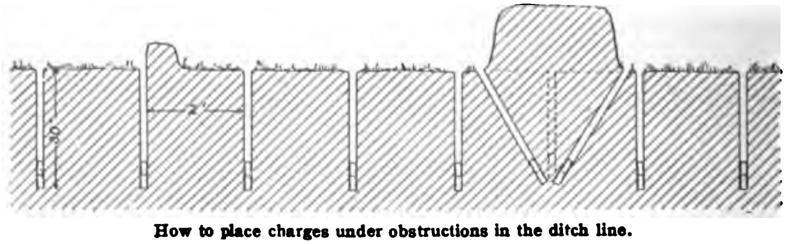
Large stumps, stones or other obstructions along in the line of the ditch require a little extra explosive. Stumps up to 6 inches through and boulders up to 18 inches in diameter will be thrown out by the regular ditch charges. Above these sizes use extra loading, as follows: For each 6 inches of the diameter, use one stick of explosive. For stumps larger than 30 inches, use 3 to 4 sticks for each foot of diameter. Put the extra explosive directly under the stump or stone.

Steel bar for making holes.

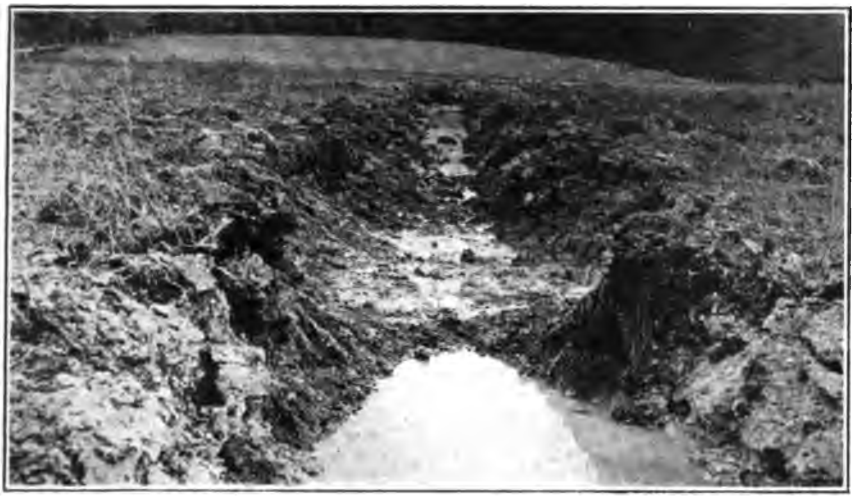
Soil auger—note long point.



A good kind of crimper.



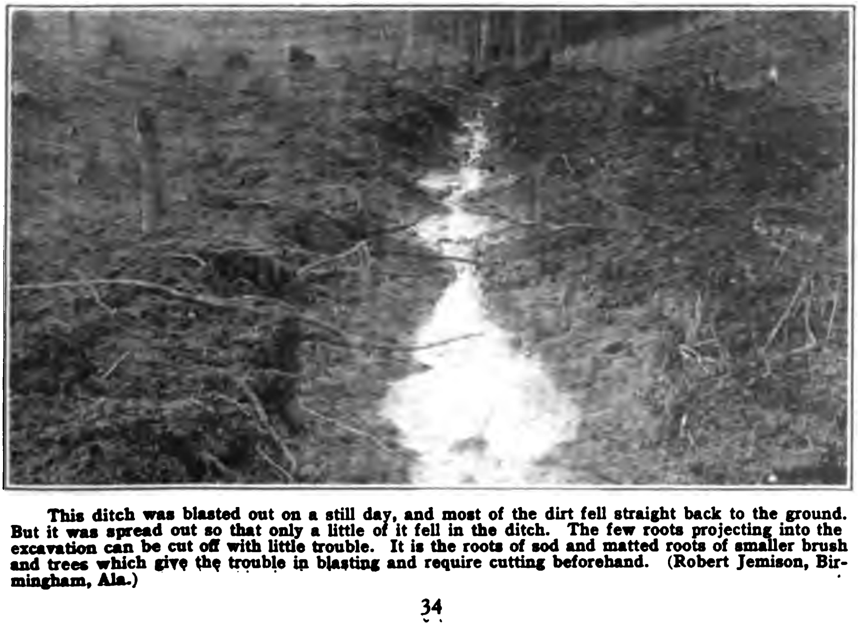
How to place charges under obstructions in the ditch line.



Through heavy sod, as shown here, blasting cuts the sides somewhat irregularly unless the grass roots are first sliced with a shovel blade or hay-knife. This ditch is well opened and entirely successful, but a good many projecting chunks of sod are left sticking from the sides.

Finishing Ditch

Ditches blasted through ground that has a raw surface and no roots will require no finishing afterwards. The edges and sides should be fairly true and even and the dirt should be well scattered. There will be few or no ridges along the ditch. Even through sodded ground and through woods and brush, when the sides of the ditch have been cut before blasting, there will be little hand work needed. If no preparatory cutting is done, however, some shoveling to smooth the sides and some cutting to take out projecting roots and sod may be advisable.



This ditch was blasted out on a still day, and most of the dirt fell straight back to the ground. But it was spread out so that only a little of it fell in the ditch. The few roots projecting into the excavation can be cut off with little trouble. It is the roots of sod and matted roots of smaller brush and trees which give the trouble in blasting and require cutting beforehand. (Robert Jemison, Birmingham, Ala.)

This work should be done right after the blast, before the water has a chance to compact the sides. If necessary, leave dams of unblasted sections 3 or 4 feet long every few hundred feet in the ditch, to hold back the water long enough for finishing. They can be blasted out afterwards. An old axe or a sharp grubbing hoe or adz will cut the ends of roots easily. But all this work can be avoided and a better ditch result if you will do the cutting before the blasting. Large clods, pieces of stumps or roots and stones in the ditch channel after blasting should be thrown out without delay.

It has been stated (page 12) that ditches for tile or pipe cannot be blasted out satisfactorily. The dirt can be loosened with light charges, however, and the shoveling or excavating by other means thereby made much easier. If the pipe is to be placed deeper than 4 feet, it even is practicable to blast a 3-foot or deeper ditch on top, leaving only a little more excavating to do in the bottom. One must bear in mind, however, that the blasting throws dirt too far away to be shoveled in to cover piping. Loosening as explained above, however, to make digging easier, does not throw the dirt away.

Two post electric blasting machine—push down type.

Preparing Charges of Explosives for Firing

What a Charge is

A charge of explosives for the purposes of these directions is considered to be all the explosives needed for a single hole with cap and fuse or electric blasting cap properly inserted in the stick of dynamite or powder (see pages 37 to 39) and tamped in the hole, ready to fire. The preparation of charges is practically the same for all sorts of farm blasting. The slight variations advisable to suit different kinds of work are not enough to call for separate treatment, since the principles are all the same.

All who use and buy explosives should read the next chapter, beginning on page 51, on the nature and actions of explosives. It is only the man who understands all the facts mentioned there who will be able to load and blast with greatest ease, speed and results.

Scope of This Chapter

It is important for everyone who blasts to understand why he does things, as well as how to do them. For that reason the following discussion of the preparation of charges is made full and complete, with due attention to all the important factors involved. Details of any particular part of the operation can be found quickly by referring to the heading desired, as given in the index.

Readers who may not desire a full discussion are referred to the following brief outline of the process.

Be careful that explosives, cap and fuse are in perfect condition. Cut a length of fuse sufficient for the hole to be loaded, making the cut clean, without dragging ends, at a slight slant of, say, 30 to 45 degrees from right angle.

Pick a cap from the little tin cap box, carefully, with your fingers, and slide it gently on the end of the fuse. With a proper cap crimper fasten the cap securely to the fuse, making the crimp close to the open end of cap. Avoid twisting or punching the end of fuse against the bottom of cap as well as drawing it away from the bottom. For wet work waterproof the joint of cap and fuse with tallow, soap or other material. Do not use thin grease or oil.

Next punch a hole at a long slant in the side of the stick to be primed. Better use a wooden punch for the purpose. The handle of the cap crimper may be used.

Insert the cap in the hole made as described, tie the fuse in place, and, for wet work, waterproof all openings in the stick. You then are ready to load.

Provide space enough in the hole at the proper point to hold the required amount of explosives in a bulk that is not too long. Be sure before you start to press in the sticks to the bottom of the hole (see page 43) that there is enough clearance to permit their easy and certain entrance. Tamp fully and firmly up to the top of the hole.

The charge is now ready to fire, which may be done by pressing the burning or flaring head of a freshly scratched match against the powder in the split end of the fuse.

Carrying Explosives and Supplies

Protection of Explosives

The place to keep the explosives is in the magazine or storage place, and not with you in the field. Carry with you in warm weather only enough for the job or the day, or in cold weather only as much as can be kept warm and in condition for firing until you are through loading. Keep explosives separate from caps.

A good way to carry the caps, fuse and small tools is in a basket. Put a piece of blanket in the bottom, to keep

out dampness when the basket is on the ground. Some blasters use an explosives box for the purpose, putting a wood handle or double wire bale on it. The tight wood box probably is a little better than the basket because it affords somewhat more complete protection to the contents.

Whatever the method of carrying the explosives, it should be well protected. This consists in keeping the hot sun off it, keeping rain and fog off it, keeping it away from dampness of the ground, and keeping it safe from meddlesome people and animals.

Many blasters prepare charges before going to the field, but it is better practice to carry along the tools and materials, and to put them together or make the primers on the spot after all the holes are made in the ground or rock, and when everything is ready for the firing except to put the explosive in place.

These remarks are given as reminders. Full discussion of proper handling and storing of explosives can be found on pages 60 to 61 respectively.

Tools and Materials Required

The first step in preparation of charges is to assemble the following: as many sticks of explosive (or parts of stick, if charges are to be less than full sticks) as there are holes to be primed; an equal number of caps; a sufficient quantity of fuse; some string; a wood punch with an end the size of a cap for about 3 inches; a pair of cap crimpers; a pocket knife. If the holes are very damp or full of water you also will need some tallow or other waterproofing material. In certain cases a sharp hatchet or axe and a block of wood will be worth having. The purpose and use of these items will be made clear later.

A handy box for carrying supplies to field.

Putting Caps and Fuse Together (Making Primers)

Fuse is described as to sizes and properties on page 60 and caps on pages 58 to 60. Readers who are not familiar with them should turn to those pages at this point. Unroll the fuse and cut off a length that will be enough, since fuse burns about 2 feet in a minute (there are variations—see page 61).

The Fuse

Three feet will give you 1½ minutes or a sufficient time to get beyond danger under ordinary conditions. The fuse, of course, must be long enough to reach out of the mouth of the hole when the charge is in place. Measure the depth of the hole before you cut the fuse.

Warm cold fuse before attempting to bend it. It may be taken into any warm room for the purpose but should be subjected to no heat greater than 110 degrees. If for any reason you have doubts about the condition of your fuse, cut off a foot or more and try it without any cap or explosive. If it will burn properly it is all right.

Be sure to get fresh ends both for the match and to put into the cap. If fuse has been cut for some time into lengths, it is well to cut off short pieces from the old ends in order to bring fresh powder right to the tips.

Cutting the Fuse

Cut the fuse off at a very slight angle or bevel—say 30 to 45 degrees, as shown in the diagram. This slant is for the purpose of giving a little space between the actual end of the powder and the explosive material in the bottom of the cap, to enable the spark to spit into material

The only way to regulate the space is to cut the fuse as directed and let the long tip rest gently against the bottom of the cap. The spark has a better chance to ignite the explosive material in the cap when it spits from the end of the fuse than when it merely burns up to the end without any space to spit into.

The end of the fuse where cut off should be clean and free from dragging ends and threads. If it is not cut off clean, part of the covering may double over the end of the fuse in the cap and keep the spark away from the explosive, causing a misfire. Be careful to keep both ends of fuse off damp ground and out of puddles of water.

If the fuse has been mashed, or is too thick to go into the cap easily, do not peel off any of the covering. Reduce the diameter by squeezing it with the cap crimpers or by rolling it on a smooth surface under a knife blade or other smooth implement. Sometimes you can reduce it by rolling it between the thumb and finger.

The very best way to cut fuse is on a block of wood with a sharp knife. The blade can be pressed right through the fuse and will make a clean cut. Another good tool is a sharp axe, to be used on a block of wood. The method of cutting is of small importance, just so the actual cut is made smooth and even enough. If you do use other tools, have a knife with you to trim up ends that are not true. Be careful to avoid twisting, pinching or otherwise knocking the freshly cut end of the fuse about, for you may shake out the powder back far enough to cause a misfire. The powder should come out flush with end.

To get one cap out of the tin box in which they came, tilt the box up on edge till some of the caps slide forward, and then pick the cap up with your fingers. Don't attempt, on penalty of losing a hand, to take a cap out of a box by running a nail or a little stick or the fuse into it in the box. Be careful you do not drop a cap to the ground or floor.

The Cap

Turn the cap upside down, to make sure there is no dirt in it, and gently slide it on the fuse till the end of the fuse just touches the bottom of the cap. Do not ram, press or twist the end against the bottom.

Crimping

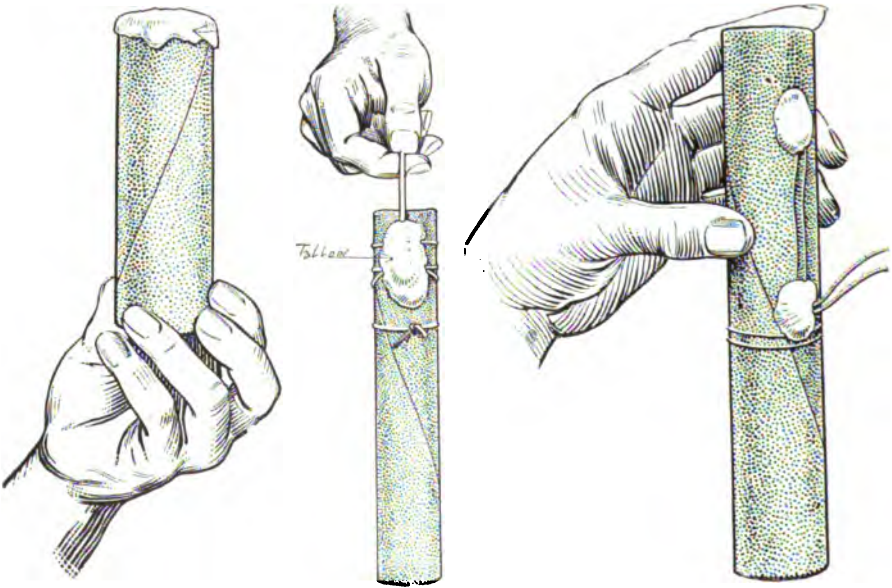
Hold the fuse with capped end up, to keep the cap from sliding off, and crimp the cap fast. This you do with the special plier-like tool called a cap crimper. The "crimp" is made by pinching the open end of the cap tight to the fuse. It should be made within the last quarter inch of the open end of the cap. Never make it toward the closed end because you might disturb the explosive material in the bottom of the cap and cause it to explode.

"Crimp" or fasten caps to fuse with a regular crimping tool. This tool does the job far better than it can be done in any other way.

Cap crimpers are supplied by

all makers of explosives. Order one or more when you buy your explosive. It is well to have an extra one about to use in case you lose one on extensive jobs.

This fastening of the fuse to the cap is one of the points in blasting where a great deal of abuse occurs. Blasters think they can take a chance with danger or with misfires, and attempt to crimp the caps some other way. Except in extreme emergency don't try to crimp a cap with anything except a regular crimping tool; but there are times when one may not have a crimper nor be in a position to wait till one can be purchased. There is a way out of this difficulty—which is to secure a makeshift crimp with something else than a crimper. It is possible to use a pair of pliers, or a small pair of pincers, and accomplish something that may hold the cap on the fuse. The best makeshift crimp is to take a fold of the cap up at one side of the mouth with a pair of close fitting, square-nosed pliers. Be careful while doing this that you do not grind the end of fuse against the bottom of cap, or pull the end back from the bottom. If the fuse should pull away from the bottom of cap a quarter inch, a misfire likely would result.



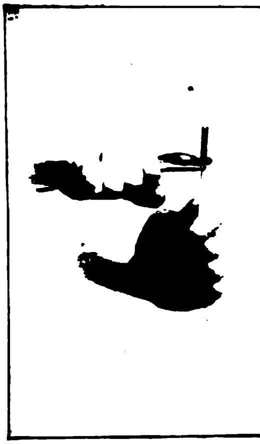
Waterproofed (tallowed) sticks ready for loading in wet holes.

Waterproofing

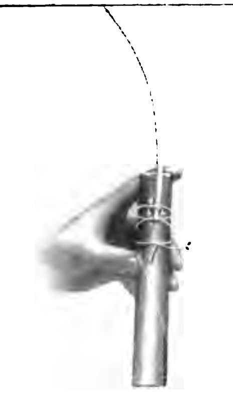
When the charge is to be placed in a dry hole, waterproofing is not needed, but in a wet hole the connections between fuse and cap must be made water-tight with tallow or soap. Do not use grease, because it may unite with the tar in the composition of the fuse cover and soften it, when the powder train will be ruined. Water in the cap will surely make it worthless.

Inserting Caps in Explosive

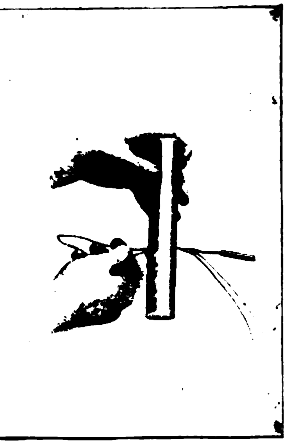
The best location for a cap in a stick of explosive for farm blasting is in a hole in the side, about an inch and a half from one end. The best position for the cap at this point is at a slant that takes it in from the side toward the center, but as near longways, or parallel with the sides of the stick, as possible.



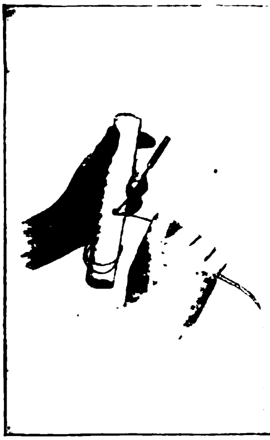
Crimping cap with the cap crimper.



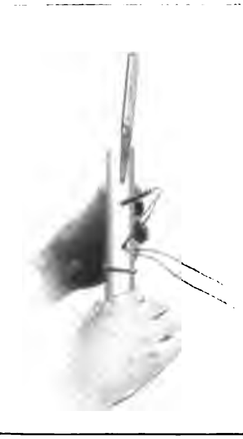
Fuse tied firmly to stick with string.



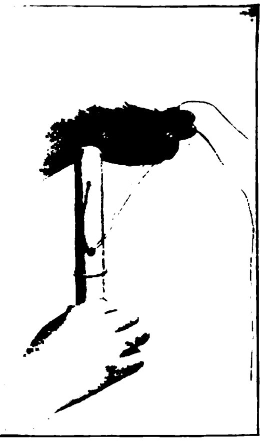
Electric Blasting—Pass the doubled fuze wires through a hole in stick of powder.



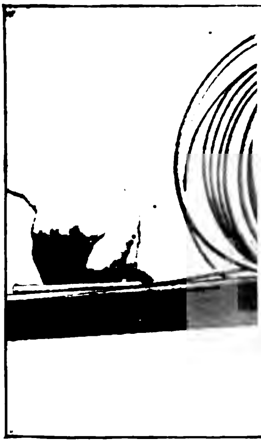
Loop the doubled end of fuze wires over end of stick.



Pull loop tight, bend wires at cap, punch slanting hole in stick high up and round to side a little.



Insert cap in slanting hole to bend of wires, take up slack in wires. (Waterproof holes if ground is wet.)



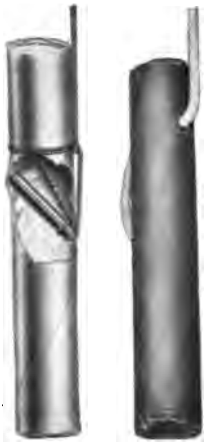
In cutting fuse from roll use sharp knife.

Taking one cap carefully from box.

Inserting fresh end of fuse in cap.

Position of Cap in Stick

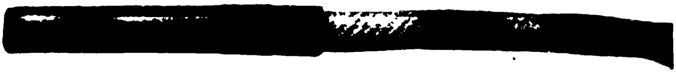
In other words, when making the hole for the cap in the explosive, make it with as long a slant down toward the other end of the stick as possible. There are reasons for this connected with superior or inferior detonation.



Bad priming.

Another style of priming much used is to set the cap in a hole made in the end of the stick of explosive, and then to tie the paper about the fuse or wires. This is good so long as it is not damaged, but experience shows that the tamping stick often bends the fuse over sharply when the primed stick is pressed into the hole and sometimes even interferes with the cap itself. With side priming there is a cushion of the soft explosive between the end of the stick and cap. End priming always is good provided sufficient care is taken in loading to prevent disturbing or displacing the fuse or cap with tamping rod.

When all the explosive is removed from its stick wrappings, the cap must be inserted in the loose explosive. This should be done by making a hole, as in a stick. But it seldom pays to take all the explosive out of stick wrappings. Nearly always you can leave a half stick of explosive intact for the cap.



A good crimp.

Making Hole in Explosive

To make the hole for the cap use the handle of the cap crimper or a wooden punch just a little larger than the cap. The hole should be large enough to let the cap in without much pressing, but should leave no air space about the cap. The depth of the hole also is important. It should be just enough so that the entire cap can be buried in the explosive, but not any deeper. If it is deeper, the cap may be forced on down to the bottom, which will leave some of the fuse in contact with the explosive (may cause burning instead of exploding of powder), or the cap may be seated just inside the wrapping, leaving an air space at the inside end or bottom of the hole, which may lower the effectiveness of the explosive.

Fastening Fuse to Explosive

When the cap is seated in its hole in the side of the stick, the fuse will extend up along the stick past the near end. It must be tied in this position, so securely that the fuse and the cap will not be pulled back in handling or by rubbing against the side of the hole when the stick is pressed down. The best way to secure it is to wrap a strong string several times below the point where the cap is inserted, then give two or three wraps about the fuse, and pull tight and tie; or take two loops about the fuse and then several wraps about the stick.

Cutting stick in two—roll it under knife blade.

When the foregoing directions have been complied with you have a stick of explosive primed with a cap and fuse. It is ready to put in the hole in the rock or ground.

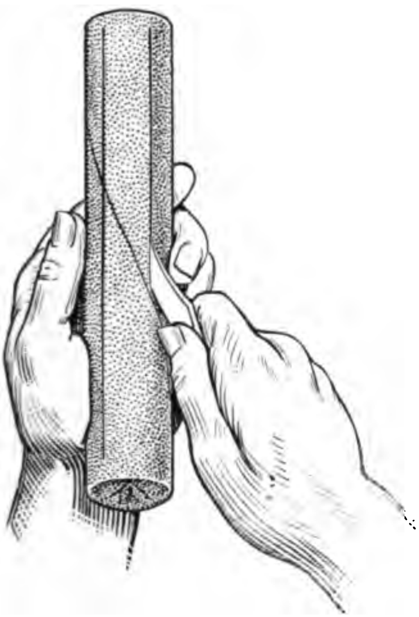
Loading Charges in Holes

Tamping rod

You will need a tamping stick. This must be of wood, and had better be about the size of a stick of explosive, which usually will be 1¼ inches in diameter, except in case of blockhole blasting of boulders, when a smaller stick sometimes is needed to go in small drill holes. Never use a metal rod for tamping. Make sure that the hole is ready. It must be big enough to allow sticks of explosive to slide down easily (except in the case of small holes drilled in rock, when the explosive all must be taken out of the stick wrappings and crumbled and pressed into the hole). Loose stones, sharp stones and roots that obstruct the hole should be removed with a bar or spoon scraper. This work must be completed before starting to load. If obstructions fall into the hole, after some of the explosive is in place, don't try to remove it by force. Make another hole at a safe distance from the first, put in another charge and fire it.

Measure the hole with your tamping stick and judge if there is space for the required charge at the right point. Nearly always a charge of explosives should be as much on a pile as possible. If one or 2 sticks are all the explosive required, it usually will not hurt to put them end to end. But if 3 or more sticks are required, to put them end to end makes the charge too long, and places the force of the blast elsewhere than where it should be.

The tamping rod should be of wood.



Slitting the paper wrapping of stick to let it swell to fill dry hole.

When your judgment tells you that the charge should be in a more or less round bulk, enlarge the hole at the point where the charge should be made. Sometimes this can be done by scraping it out at the bottom with a toe-bar or spoon-bar. Again, if much enlarging is required, it is well to use a small amount of explosive to secure it. This is called springing. To do this prime about a quarter of a stick as usual, and push it to the bottom of the hole. Use no tamping. After it is fired wait till the hole cools, and you will find a cavity large enough for your full charge.

It is better to avoid springing holes if you can, on account of the fact that the cavity often is enlarged too much, and the surrounding earth is loosened so much as to injure confinement. (See page 51 on detonation). A great deal can be done by scraping the small auger hole out to 2 or 3 inches in diameter at the bottom and then causing the

sticks to enlarge and fill the hole solidly. To accomplish this enlargement of sticks, slit their wrappings 3 or 4 places lengthwise, from end to end. Then press them home with the tamping stick. They will expand and shorten. Four to 6 sticks in this way can be got into the full length of two.

Still another way is to take the explosive entirely out of the stick wrappings, and with the help of a tin or paper tube, such, for instance, as calendars are mailed in, funnel it down to the bottom of the hole. But neither this method nor slitting the sticks is wise in wet holes. It is true that nitroglycerin powders will stand considerable water, but the safe rule in wet blasting is to leave the sticks intact. Ammonia powders or dynamites will not stand wetting inside the paper of the sticks without damage. (Never under any circumstances cut, break, unwrap or punch holes in explosive that is frozen. You invite an explosion in your hands when you do).

When there is more than one stick in the charge, place the primed stick on top of the others—put it in the hole last or next to last—when using the cap-and-fuse method of firing.

Be sure that all parts of the charge are in firm contact. It will not do to have air spaces, or dirt, or wrinkled paper between the sticks. While all the powder likely would go off under these conditions, it will not do as much work as it should.

The sticks of explosive may fit tightly in the holes. In that case do not ram or pound them, but press firmly against them, one at a time, with the tamping stick. Press the explosive into tight contact with the sides all round, at the bottom of the hole.

Tamping

Tamping

Tamping is a necessity. The charge should be tightly confined. It is only in springing holes and sometimes in digging post holes that no tamping is advisable, and in ditching that the quantity needed is less.

When the explosive is in place at the bottom of the hole, start the tamping by rolling in some loose ground. Keep the tamping stick working up and down to seat this ground against the explosive, though make no effort to get it tight till there is a few inches or so over the explosive. An exception to this rule is in the case of blockhole blasting of boulders and ledges, when damp clay tamping should be packed solid all the way down to the explosives. The rule for the least contents of tamping that will do good work is that it should be 6 or 7 times as deep as the hole measures in diameter.

If the tamping is less than this, the best results will not be secured, hence deep holes often are necessary for the sake of confinement of charge as well as to contain the amount of powder used.

Hold the fuse to one side with one hand while the tamping stick is worked with the other hand. Rake the dirt to the mouth of the hole and be careful to get in the hole only earth—not clods, sticks, grass, etc. Be very careful not to damage the cover of the fuse with the tamping stick.

Fill the hole to the top with tamping, and make it tight. The best material for tamping is moist clay. Tamping material always is better when made *wet* enough to ball. In fact, there isn't much better tamping than water itself in the hole, when it can be made to cover the charges deeply enough. Use the heaviest earth within reach, and if it is dry, better carry some water for wetting it.

Firing

Stick the burning head of a match against the powder to light fuse surely.

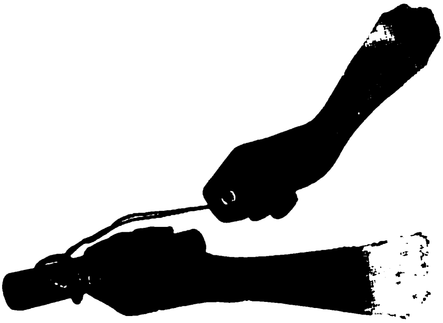
The free end of the fuse will stick out of the hole filled with tamping, say about 4 inches. Your remaining work is to set fire to the powder in the fuse, till it begins to spit continuously. Split the end of fuse with your pocket knife to make it light easily. Put the flaring head of a freshly scratched match against the powder exposed by the cut.

Preparing Charges for Electric Firing (Making Primers)

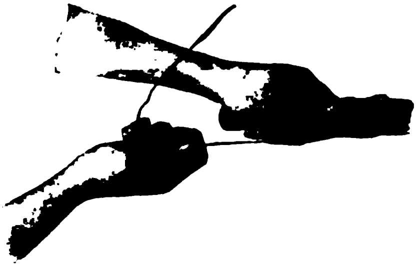
Up to this point in the directions for preparing charges the text has spoken only of caps and fuse. When the firing is to be done with an electric blasting machine instead of fuse, you must use electric blasting caps.

These come from the makers with the wires already fastened in them. (See pages 59 and 60.) They are ready to be inserted in the stick of explosive without any preparation such as ordinary caps and fuse require.

Make a slanting hole in the stick of explosive just as is described on page 41. Into this insert the electric blasting cap, letting its wires project just as the fuse does when fuse is used. Then tie the wires to the stick with a string as fuse is tied, to prevent the cap from being pulled partly or entirely out of the hole.



Bad method of fastening wires. It is better to tie them.



Bad position of cap in stick, and of cap wires.

It is a little difficult to tie the wires tight enough with a string to prevent slipping. Another way to fasten them securely is to pass the wires through the stick. To do it punch a hole straight through the stick of explosive about the middle. Double the wires about 6 inches back of the cap and pass the doubled end through this hole. Then loop the doubled ends from the other side back round the lower end of the stick. Take up the slack in the wires and you will have a sure fastening. The cap can be inserted in the stick at another point, in a slanting hole, just as described previously.

In fixing wires of electric blasting caps to sticks, avoid crossing them and avoid bending them sharply or in any manner that will break their insulating. If the insulating is broken it likely will cause a short circuit, which will result in a misfire. *Never take a half hitch about the stick with the wires.* Do not pull at the wires and the cap, because to do so may break the fine bridge wire that causes the cap to explode when the current goes through.

Load these primed sticks the same as is directed for fuse primed charges. Be careful to avoid rupturing the insulating on the wires with small stones in the hole or with the tamping rod.

The finishing of the tamping leaves two wires projecting from each hole. They must be connected with the blasting machine or other source of current with connecting wire and leading wire, in the manner described fully on pages 55 to 57. Further discussion is not needed at this point.

Some General Suggestions

In priming sticks of explosive with fuse and blasting cap, you must be careful to avoid permitting the fuse to touch the explosive. High explosives will burn like gasoline or coal-oil. They are very easily set on fire by sparks spitting from fuse. When they are burning the explosion will be very much weaker than it otherwise would be, and will give off noxious gases.

A very frequent cause of misfires is the bending, kinking and crooking of fuse. This is especially frequent when the cap is inserted in the center of the end of the stick of explosive and then carelessly forced over against the side of the hole by the tamping stick and tamping material. Keep the fuse straight, and never under any circumstances lace it through the stick of explosive. That is a sure cause of trouble.

If it becomes necessary to remove a cap from a primed stick of explosive, do it gently and carefully, and unless the cap and fuse are immediately to be inserted in another stick, destroy them both by lifting a shovelful of earth and putting the cap under the ground in the hole, after which light the fuse and go away.

It is better not to lift or carry the primed stick of explosive by the fuse or wires when it can be helped. When a practice of carrying primed sticks by the fuse is made, misfires and poor explosions will be caused, not every time, but often enough to make it wiser not to do so. The cap often is pulled back in spite of the tie string.

Where explosives that are subject to water damage are used in work that is wet, matters can be helped by making the sticks waterproof with tallow, paraffine or other suitable material. It is practicable to stop all the seams on the sticks, load and fire without delay, even with explosives that would be put out of business if the water got at the actual material instead of only at the wrappings of the sticks. Pay particular attention to waxing or tallowing the place where the cap and wires go into the stick.

When doing wet blasting, use every care to keep the outer end of the fuse from dropping into the water or from resting on damp ground. The inner wrappings of fuse and the powder train itself take up water like a blotter. On a very foggy day it is well to keep fuse in a closed box. Mist and rain of course, will damage it.

Explosives and Blasting Supplies

The catalogs of manufacturers are not intended to give all the fundamenta facts about and the differences between the various explosives. To do so would take too much space. They give the trade names and the measurements and weights of sticks and boxes, demanded by purchasers, and are prepared on the supposition that blasters and buyers of explosives know what they need. This bulletin includes explanations of the names under which blasting explosives are made and marketed, outlines their properties, and makes clear the work and conditions for which each grade is intended and suited.

Explosives

Names

There are scores of different kinds of explosives made and used for blasting purposes, and many dozens of different names used for them. The most familiar name of any explosive in America is dynamite. Another familiar term is powder. Other names are farm powder, quarry powder, contractor's powder, coal powder, stumping powder, Judson powder, gelatin, blasting gelatin, R. R. P., giant powder, blasting powder and dozens of others.

Nearly every one of the explosives designated by these names are made in several strengths, and in qualities to suit varying conditions. For this reason figures and other marks are attached to the names to distinguish the grades. In addition to this some of the names are used to designate not only one certain explosive but several widely different ones. This is particularly true of the names dynamite and powder. The selection of names in the preceding paragraph is made for illustrative purposes, and is not to be taken in any sense as a recommendation of those explosives for any purpose. The recommendations are given in detail on other pages.

Differences

All blasting explosives are not made from the same ingredients, and they differ a great deal in many other ways than in quality, as quality is generally understood. You can buy cornmeal that is good, bad or indifferent, but when you buy explosives you will find there are few which can be classed as of poor quality. Nearly every standard kind and grade is of excellent quality for some particular purpose and condition. And practically every one can be classed as of poor quality for conditions and purposes to which it is not suited.

Nor is the difference one of size of stick or grain, as the case may be, though this is one element. The main differences are ones of strength, quickness or speed of gases, sensitiveness, resistance to cold and to water, density, fumes and cost. Some explosives are suitable for wet work, and others only for dry work; some are adapted to blasting hard, tough rock, others to blasting ground only; some freeze when chilled a little; others can be exposed freely without freezing. And it should be noted that many of the better explosives of to-day have been developed during recent years and are comparatively new. The explosive to buy for any particular work is the best one on the market for all the conditions involved.

Explosive Ingredients

Black blasting powder has been known and used for several hundred years, and it is practically the same to-day as it has been for a long time. It is composed of saltpeter or nitrate of soda, sulphur and charcoal. It does not vary in strength, and varies little in other properties.

The dynamites and high explosive powders have little or no relation to black blasting powder. They depend for their explosive force on other explosive chemicals the best known of

which are nitroglycerin and ammonium nitrate. It is not necessary in this brief description to name additional explosive elements.

The first dynamite was made in Europe by mixing nitroglycerin with a light spongy earth, and packing the mixture in paper tubes as sticks of dynamite and powder are packed to-day. Nitroglycerin itself is a wonderfully efficient explosive when it can be controlled, but it is so dangerous and unstable that it must be mixed and treated to make it safe enough to handle.

As other explosive chemicals become better understood, it has been found of advantage to substitute materials that are explosive for the light earth used to absorb the nitroglycerin. And more than that, the nitroglycerin itself has been displaced to varying degrees in some of the powders and dynamites by ammonium nitrate and other materials. Few blasting explosives contain no nitroglycerin at all, but many contain only 4 or 5 per cent. of it. Each of these combinations of materials, or formula, has its own peculiarities in addition to variation in strength, all of which information it is well for a buyer and blaster to understand.

The explosives marketed as "straight dynamites" and "straight powders" are made from nitroglycerin. Those made from an ammonium nitrate base are called by many manufacturers "extra" dynamites and powders. Gelatin dynamites and blasting gelatin are nitroglycerin explosives in which the nitroglycerin has been combined with gun cotton. The various special mine, quarry, stumping, farm and other miscellaneous dynamites and high explosive powders on the market are not so named that their ingredients can be determined without a statement from their makers.

Strength and Quickness

The power of an explosive and its violence are two different qualities. The power, or direct strength, is due to the volume of the gases. If a pound of a certain explosive gives, for instance, 1,000 cubic feet of gas when completely detonated or fired, while a pound of another explosive gives 500 cubic feet and a pound of a third gives 2,000, the lifting power of each explosive will be in direct proportion to its gas volume.

But the violence of the gases depend, not on their volume, but on their speed. If they are comparatively slow in forming and in forcing their way out of their confinement they will break out large cracks and escape through them, pushing the material aside. If they are very fast or quick, they will grind and pulverize everything they come in contact with, and throw out the whole side of the confining material, but will not crack it so far.

The matter can be made clear by comparing a push with a blow of a hammer. Both may have equal power, but the effects on a block of wood, for instance, at the point where they are applied are very different. The push will move the object almost without marking it. The blow may move it, but it is sure to leave a mark of greater or less depth, depending on the nature of the hammer and its speed. A still better comparison, perhaps, is that between the blow of a sledge and of light hammer. It is possible to hit a blow of as much power or weight with one as with the other, but the material at the point where the blow lands with the light hammer will be badly dented, or maybe broken. The reason is that the light hammer moves with much greater speed.

In quarries blasters make use of these facts in order to get the rock broken out in pieces of the size preferred. When they want large pieces they use an explosive with sufficient power to break the rock, but, comparatively speaking, with a slow speed of gases; when they want small pieces and much shattering, they use an explosive of the same or greater power but with swift and violent gas action.

For each result and for each material a certain power is required and a certain quickness of the gases is best. By way of illustration, take soil blasting for tillage purposes. There is no object in violently grinding the earth at one spot while surrounding earth that might be reached is left untouched. A proper explosive for this purpose is one that will have enough pulverizing action, that will lift and shake up the soil, and that extends its effects for long distances. For an example of the other extreme, take mud-capping rocks. For this work the explosive cannot be too violent in action. The gases, backed up by the rapidly yielding wall of air behind them, must strike the rock a crushing blow in the minimum of time.

Nitroglycerin and ammonia powders and dynamites, for all practical purposes, are of equal strengths when of equal markings. The strength is indicated accurately by percentage figures.

Nitroglycerin explosives are uniformly quicker and more violent in action than ammonium nitrate explosives, and the more nitroglycerin there is in the explosive the quicker it is. The ammonia explosives are not as quick, in any strength, as the corresponding nitroglycerin explosives. Therefore a 50% nitroglycerin powder is more violent than a 50% ammonia powder, and a 20% ammonia powder is much less violent than a 50% grade.

When the object is to shatter and reduce to fine fragments the material to be blasted, the proper explosive is a quick one, while when the object is to lift and shake up the material the best explosive is a slow one. (See table on page 50, also detailed recommendations on pages 22 and 25.) But there are other factors that must be considered.

Nitroglycerin explosives resist water better than ammonia explosives, but if the cartridge wrappings are not broken or opened, ammonia dynamite or powder can be loaded in wet holes with entire satisfaction. The firing should not be delayed any longer after loading than necessary, and it is wise to plan the work so that it may be done at the longest within a half hour after loading. Storage in a damp place will weaken explosives, especially ammonia explosives.

Gelatin explosives resist water very well, and may be loaded in wet holes, or under water, with assurance that they will explode with their full power. Blasting gelatin is entirely water-resisting.

Explosives will freeze, and when in this condition are dangerous, and cannot be fired properly, if at all, with a cap of any kind. They *must* be thawed and they must be handled very carefully if they are to be used. On no account attempt to cut the wrappings, to break a stick, or to handle the frozen explosive in the ordinary way. (See pages 51 and 52 for directions for thawing.)

Regular nitroglycerin explosives are quickest to freeze. Others, known as "Low Freezing," will stand much lower temperatures without showing trouble in this respect.

Freezing

Ammonium nitrate explosives also will freeze, but not quite so quickly as nitroglycerin explosives. They too are made on both regular and low freezing formulas. The low freezing ammonia will stand more cold than the low freezing nitroglycerin.

The regular explosives will freeze at temperatures of 45 to 50 degrees. The low freezing explosives will not freeze and become solid till the thermometer gets down to at least 25 degrees, and in practice many of them can be used right out in the open without any trouble when the temperature is down to zero and below. The length of time the powder is exposed to the cold has much to do with its freezing.

The safety point for both low-freezing explosives and regular explosives is not a matter of rule, but of watching the explosive. When high explosive powder or dynamite is frozen, the sticks will be hard, and when it is partly frozen they usually will have a mottled appearance on outside of the paper wrappings. The hardness may only be in spots. When not frozen, the sticks should be a little soft all over. No explosives should be handled much, cut, punched, rubbed, broken or loaded when they are frozen. They cannot be exploded satisfactorily and such acts are dangerous.

In cold weather always use the low freezing grade of explosives, for the regular grades may freeze in the holes before they can be fired. It is a good plan to use the stronger caps, say No. 8 (see page 50) in cold weather. When a charge of explosive is chilled but not frozen it can be fired satisfactorily by a heavier impulse (blow and heat) than ordinary, such as a fresh No. 8 cap gives. The low freezing explosives do not differ in action from the regular explosives, and are just as efficient.

The gases of explosives naturally are more or less objectionable when breathed. Some of them are poisonous, others are merely disagreeable. When explosives are used out in the open the gases are taken up by the air so quickly that none of them give any serious trouble, though they do cause headaches. It is only in tunnels and deep shafts where the air is confined that the matter of fumes is important, not on farms.

Other Properties

Special explosives have been developed for tunnel and mine work, but they are not important in agricultural work. The only fact about fumes worth knowing in farm blasting is that nitroglycerin explosives either in the form of their gases or when absorbed through the skin will cause headache somewhat quicker than ammonia explosives. The so-called fumeless explosives always cost more than any ordinary dynamites and powders and are not suited to farm work. Farmers will do well to buy grades of explosives suited for their special purpose.

Appearance of Explosives

Dynamites and most high explosive powders are light-colored materials that look like fine, sticky sawdust, and they always are packed in "sticks" made with cylinders of tough paper. These sticks vary in diameter and length. The standard is 1¼ inches in diameter and 8 inches long. This is the size carried in stock by dealers and in the magazines of the makers. You can get special sizes of sticks if you need a considerable quantity, varying from ⅞ of an inch in diameter to 4 inches. Sizes other than the standard 1¼ by 8 inch may cost more per pound than the standard owing to higher packing cost.

Dynamites and high explosive powders are packed in wooden boxes containing 25 pounds or 50 pounds, as you prefer. A 50-pound box of 20% ammonia powder or dynamite will contain about 105, 1¼ by 8 inch sticks. If of 20% nitroglycerin, it will contain about 98 sticks. If of gelatin dynamite, or blasting gelatin, it will contain about 88 sticks.

A word should be said here about the cost of explosives. No quotations can be given because the prices vary in different parts of the country and from time to time. The ammonia products usually are cheapest. The cost of course follows the percentage strength, the low percentages cheaper and the high percentages dearer. Gelatin explosives cost about the same as straight nitroglycerin explosives. The special explosives for use in mines, tunnels, quarries, railroad construction work, etc., often cost more than the explosives recommended here for farm work.

In buying explosives look first to getting the one that is best suited to the work to be done, and aside from that the cheapest one. There would be no object in using a straight nitroglycerin or a gelatin explosive when one of the ammonia farm powders would do the work, for the former explosive cost much more than the latter.

To avoid "explosive misfits" it is well to consider carefully the nature of the material to be blasted, the conditions of weather, water, etc., and the results wanted. The kind of explosives to use depends on these factors. Keeping in mind the facts mentioned in preceding paragraphs, the reader will see that there is a type of explosive made for almost every condition and kind of work, and will understand why one will not suit the work of another.

As the briefest and clearest way of giving general suggestions for the type of explosive best for different agricultural work, a table follows: (Detailed recommendations are given on pages 21 and 25.)

Explosives Recommended for Different Work

Stone blasting—mudcap	Straight nitroglycerin or ammonia dynamite, 50% or 60%.
Stone blasting—undermine	To break, same as for mudcapping; to throw out, use any dynamite or powder of 20% strength.
Stone blasting—blockhole	To shatter well, any high percentage dynamite or powder; to break into large pieces, 20% ammonia dynamite or powder.
Soil blasting—for subsoiling and for tree planting	20% ammonia dynamite or powder.
Ditching—electric firing	20% to 40% ammonia explosives; (nitroglycerin is equally effective); in loose dry ground, high percentage nitroglycerin explosives.
Ditching—transmitted detonation	Straight nitroglycerin dynamite or powder, 50% strength.
Stump blasting—in medium and heavy soils, wet or dry	20% nitroglycerin or ammonia dynamite or powder.
Stump blasting—in dry sand and other light soil	50% nitroglycerin or ammonia dynamite or powder.

If you are in doubt as to the best explosives for your particular work it is well to write to the manufacturer you prefer, asking which of their grades and brands would be most suitable.

Detonation

It is well known that black powder is fired by a spark, and that dynamites and high explosive powders cannot be fired by a spark but require a shock and heat. It is not so well known that there are great differences in the nature and effect of the explosion of any powder or dynamite, due to variations in the way it is fired.

Firing, Exploding or Detonating

An explosion of powder or dynamite is the result of a very sudden creation of a great volume of gas from a smaller volume of powder. The kind and amount of gases produced by any high explosives depend on the kind and amount of shock used to fire the charge, and on its confinement.

The effect of lighting a piece of unconfined dynamite with a piece of fuse without a cap on, is that the dynamite will burn fast without exploding and make a dense smoke which has a bad smell and produces severe headaches. This is simple combustion. If the piece of dynamite is confined closely and lighted in the same way it will explode, but will give off similar bad fumes. If a weak cap is used on the fuse, or the dynamite is set off by a fall, the dynamite will be partially detonated, and explode with considerable force, but it still will give off the bad fumes and smoke. The same piece of dynamite fired with a No. 6 or 8 cap will be completely detonated, and will explode with great violence and force, even when unconfined, except by air, and will give off very little smoke.

The last-named explosion is detonation. It is produced by a violent shock in connection with intense heat. Nitroglycerin is 5 times as strong as black blasting powder when exploded by fire, and 10 times as strong when detonated. This explains the enormous force given by detonation as compared to simple explosion.

But detonation itself is no set thing that always takes place the same. There is good, or complete, or full detonation, and there is partial detonation. In case of incomplete detonation, or any detonation at a less speed than the greatest for any particular explosive, the gases formed are not what they should be. For one thing, they are more noxious or poisonous. The more powerful and severe the blow delivered by the cap, the more quickly does the chemical action take place in the explosive. It is only when high explosives detonate with their greatest speed that their maximum power is generated.

Air spaces about the cap in the stick of explosive cushion its blow and weaken detonation. It is the nature of the initial detonation of the powder right around the cap which governs the nature of the explosion of the whole charge. A blaster should understand the importance of setting up *complete* detonation in order to get the greatest amount of force out of explosives. Sometimes explosives lose as much as 20% of their effectiveness when fired with weak caps. Lack of confinement has a similar effect. Sixty per cent. dynamite poorly detonated is less effective than 40% well detonated.

When explosives become chilled it is difficult to detonate them properly with the usual cap, hence the advisability of using a very strong cap in cold weather—a No. 8. Many of the holes are frequently loaded for some time before firing, and even if the powder is soft and normal while charging, it afterwards becomes somewhat chilled in the cold ground.

Cap Means Detonator

Throughout this and other bulletins in this series, the terms caps and electric blasting caps are used in speaking of the exploders used to fire the charges of dynamite or powder, although in the field and among manufacturers the same articles are called by the terms "detonators," or "electric exploders."

Thawing Explosives

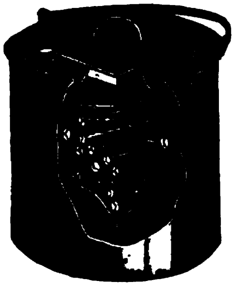
It has been pointed out (on page 49) that regular explosives chill or freeze at temperatures of 45 to 50 degrees. With the increase in the number of low freezing explosives that seldom need thawing, the necessity for doing the thawing on farms is not as frequent as it used to be.

Frozen dynamites and powders are dangerous materials, and whenever the temperature is near the freezing point for them, the sticks should be inspected before using to see if they show any of the hardness that indicates chilling. If so, handle them very carefully till they are thawed. Dynamites and high explosive powders will be a little soft to the pressure of your thumb when they are not frozen.

Frozen Explosive

Frozen explosives are dangerous because they are very much more easily exploded in the course of ordinary handling. They are more sensitive to friction and to blows of tools. The sticks may explode when dropped to the ground or floor, when sticks are broken in two, when wrappings are cut with a knife, when cap holes are punched with a stick, or when they are shoved into a hole with a tamping stick. At the same time they are so much less sensitive to the direct shock of a detonating cap that they cannot be fired properly with a cap. Therefore the rule must be laid down that frozen sticks of high explosives never must be cut or ruptured or used until they are thawed.

When nitroglycerin freezes it crystallizes, therefore the nitroglycerin in dynamite or powder tends to separate from its absorbing materials into small crystals. When the dynamite is thawed slowly with sticks lying on their sides, the nitroglycerin is reabsorbed as fast as it liquefies. But when thawed too fast, the nitroglycerin is liable to run out of the sticks before it is reabsorbed. Quick thawing will damage explosives a great deal more than they would be damaged by freezing followed by long, gradual thawing.


One type of thawer on the market.

Thawing is a dangerous operation when not done right. It probably is correct to state that more accidents with dynamite have occurred in the course of improper thawing than for all other reasons put together. At the same time proper thawing is entirely safe.

Causes of Accidental Explosions

Two of the most frequent causes of accidents while thawing explosives are in putting the sticks into water or steam, and putting them on hot stoves or stones. Water, and especially hot water, forces the nitroglycerin out of the sticks. The free nitroglycerin goes to the bottom, and explodes at the time of the first increase in heat, or first light blow. When sticks of explosives are laid on hot material the nitroglycerin also runs from the paper wrappings and drops of it fall to the stone or metal. This almost always causes an explosion. At about 350 F. degrees of heat, which is only a little more than that of boiling water, the nitroglycerin will explode without a shock

Safe Thawing

Examine your explosives a day or so before you are ready to use them, and if they show that they are frozen, proceed to thaw them in one of the following ways: Use only a *DRY* warmth. Use no temperature higher than is comfortable to the hand, or the limit may be set at 100 or 110 degrees. Use no heat of any kind that cannot be controlled with certainty. If you do this you will be safe.

Every large maker of explosives will supply thawing apparatus that is safe. Sometimes this is a double kettle arranged so that the sticks of explosives can be placed in the inside vessel, while the outside vessel can be filled with warm water and a blanket can be spread over the top. Other more elaborate thawers consist of a vessel containing watertight tubes just big enough to hold sticks of explosive, running through a space to be filled with warm water. The catalogs describe these ready-made thawers in detail.

Home-made thawers can be arranged with two buckets, one small enough to hang inside the other. Put the sticks inside the small one and warm water around the outside, in the big bucket. Another good way is to put a five-gallon can of warm water inside a barrel, or box, and pile the sticks of explosives in the barrel around the can. The top of the barrel should be covered with a blanket. Or put the water in the barrel and the explosives in a can or bucket. A small closet of course can be used instead of a barrel. A can of warm water can be set inside a magazine to keep the temperature up.

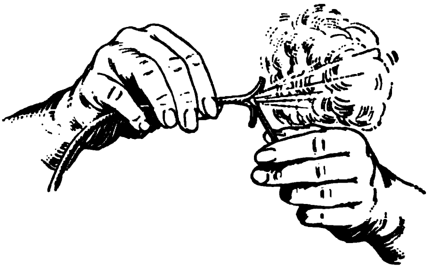
The old-fashioned manure pile method of thawing is reliable and safe, though a good deal of trouble. This consists in burying a box somewhat larger than a box of explosives in fresh horse manure, and placing inside it the box of explosives to be thawed. A foot or more of manure must cover the box, and a small pipe or tube should be inserted for ventilation. The manure must be fresh. Allow at least 10 hours to thaw a box of dynamite or powder in this way. Twenty hours is better.

Sticks on Sides

The box of explosives can be taken into any warm place that is dry, but if this is a building you must take your own risk of fire and accident. Watch the box and the sticks to see if the freezing and thawing causes the sticks to leak free nitroglycerin. If any of this leaks out of the stick and gets on the floor it must be washed up according to directions in paragraphs on storage. (Pages 61 and 62.) The sticks of explosives had better be piled irregularly rather than in tiers, for thawing. They will rise in temperature quicker in this way. They always must lie on their sides rather than stand on end.

Electric and Fuse Firing

The very best way to light fuse is to split the end for an inch or less, and stick the burning head of a freshly scratched match right against the exposed powder at the head of the split. This will light the fuse even in a strong wind.



Fuse and Cap Firing

Where there are very many fuses to light in succession, as in subsoiling, it sometimes is of advantage to use a gasoline or other torch, holding the hot flame under the fuse for an instant. Whatever the method, do not leave till you see the fuse spitting sparks and smoke swiftly and regularly. Further discussion of fuse firing, except as to its adaptations, is not needed.

Electric Firing

Farmers who have only a few stones or stumps to blast, or who are planting a few trees or doing a little subsoiling, will not need any other method of firing than by caps and fuse. Ditch blasting in ground not watersoaked demands electrical firing, while the blasting of large stumps, particularly if green, and in sandy soil, as well as the blasting of large rocks, is made easier and cheaper by electrical firing. For large amounts of almost any blasting except that of tree beds, subsoiling and very small stumps and isolated small boulders, the purchase of an electric blasting machine and the necessary wires is justified by the advantages of the electric methods of firing.

A good reel for leading wire.

Advantages

The primary reason for the superiority of electric firing over fuse firing is that several charges may be exploded at once; the different charges will increase the efficiency of each other. Thus in ditching, you can fire many charges in a row and make a perfect ditch. In stump blasting several small charges very often will take a stump out better than one large charge, and in orchard, and garden subsoiling the simultaneous blasts frequently are of advantage.

Electric firing is more certain when the charges are under water. The danger from misfires due to moisture as well as from some other cause is reduced. Should misfire occur, you are safe in going to the charges as soon as the wire is disconnected from the blasting machine. With a fuse you must wait some hours to be safe. When several charges, as for instance, several boulder blasts are to be fired, you can make one trip to safety do for the lot, instead of having to travel back and forward for each shot. Finally, the intelligent and careful use of electric firing, with its possibilities of two or more small charges doing the work of one large one, and its other economies, will save considerable explosives.

Electric Machine

All the makers of explosives supply electric blasting machines. The machines are small boxes of wood or metal, containing a modified magneto with a handle on top that you either push down or pull up, depending on the make of machine, to operate and to fire the charges. The machines are made in various sizes and capacities to fire 3, 10, 30, or more charges at once. The 10 charge machine weighs about 10 pounds. Full directions for operating and caring for the machines always accompany them.

For electric firing, in addition to the machine, you will need electric blasting caps, connecting wire and leading wire. The leading wire is copper wire large enough to carry the amount of current required for the number of charges to be fired simultaneously. It is covered with insulating material, and is made strong and durable to stand much use.

Duplex Leading Wire. (Actual size.)

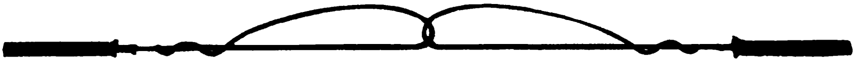
Wiring

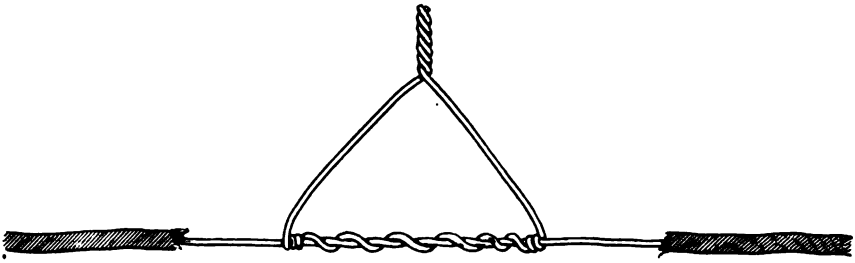
To make the circuit from the blasting machine to and through the charges and back again, you must have two strands of leading wire. It comes from the explosive makers in single-strand form, which must be doubled, and in what they call duplex form, which has two strands of insulated wire twisted together or wrapped together under one cover.

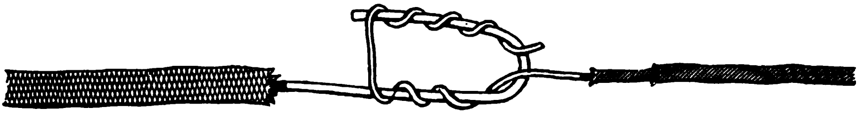
Connecting wire comes on spools.

The two small copper wires that are fixed in the electric blasting caps (see page 59) should be long enough to reach out of the holes. They may be bought in a variety of lengths, but 4 or 6 feet are regarded as standard. If the charges are close enough together so the wires can be connected, no connecting wire will be needed; but whenever the distance between is more, the charges must be connected, and connecting wire is the right thing to do it with. There is no particular limit for the distance between charges that may be connected for firing together, up to 25 feet or more.

Electric Blasting Caps


A very bad connection—a cause of misfires.


Good connection for electric cap wires.

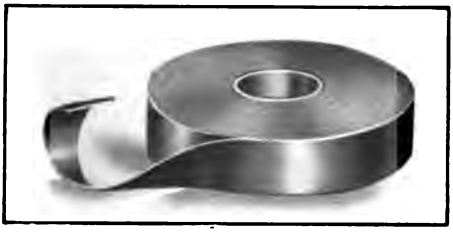

Good connection for small cap wires and large leading wire.

The diagrams in these pages will show how to make electric wire connections. Cut away the insulating on the wire ends and wrap the ends together tight. Wrap them for two inches. Looping the wires will not do. Be careful to scrape with a knife or stone the wire ends to make them bright before wrapping them together. Corroded or dirty connections are a cause of misfires.

Wire Connections

If the leading wire gets broken and must be spliced, solder the connection after wrapping the ends together, then wrap the joint with tape to

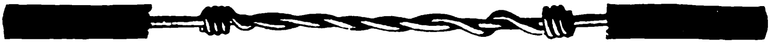
insulate it. Ordinary tire-tape is good, but a better way is to wrap the joints with special rubber tape underneath and to cover this with the tire-tape.



Tape for wrapping joints and broken insulating.

When only one charge is to be fired, connect the ends of the 2 strands of the leading wire to the 2 electric blasting cap wires and connect the other leading wire end to the blasting machine posts. The connection with the electrical blasting machine should be made the last thing before firing, after you are sure that the charges are all ready and after every person and animal is out of the way of the flying pieces.

When the blast is all connected together ready to fire, except attaching the leading wire to the machine, give the handle of the machine one or two light strokes, to make sure that it is working smoothly and to charge the magnets. Then attach the leading wires to the binding posts on the machine, making sure that both the binding posts and the wires are bright and clean where they come together. Raise the handle of the machine to its full height and push it down with speed. When the handle starts on its downward stroke, the pinion immediately clutches the armature and starts the generation of current. The current, growing stronger as the stroke proceeds, causes considerable resistance toward the end of the stroke. The current generated is directly in proportion to the speed with which the handle is pushed down, especially just before reaching the bottom. Any let up toward the bottom will cause a drop in the current and may result in misfires. Therefore, make it an invariable rule, whether the shot be large or small, to bang the handle down hard and carry the stroke with all possible speed to the bottom. Try to knock the bottom out of the box. Machines which operate by the twisting of a handle must be handled equally quick.



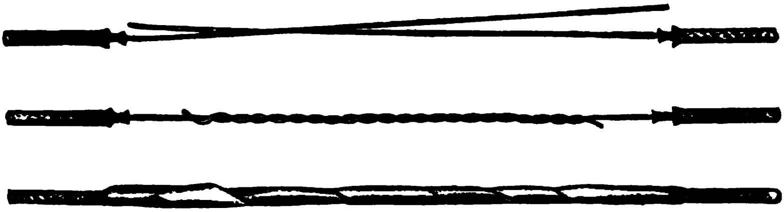
Very best wire connection, ready for soldering if need be. (Excellent for leading wire.)

When more than one charge is to be fired the different charges must be connected together. The diagrams will help you to understand how this should be done. For nearly all agricultural blasting the connection in one series is the best—that is, connecting each charge to the next one and so on until they are all joined, with one loose electric blasting cap wire from the two end charges of the series. (See diagram A and D, page 57.)

Once in a while, where the series is long and the charges are in a line, you can arrange to have the 2 loose wires at the same end of the series by making the connection, not to each next charge in the row, but to the one beyond and at the farther end doubling back and connecting the missed charge. Do not use this method where it involves many splices with connecting wire.

Connections in parallel sometimes are desirable in the case of ditches, or other extensive blasting. To make them run a piece of wire away from one leading wire strand along the lines of charges and connect one wire to each charge. Then run another similar piece of connecting wire connected to the other strand of leading wire, and attach to it the other cap wire of each charge.

But to fire charges by means of parallel connections takes so much electric current that a blasting machine cannot be used. Generally speaking, parallel



Method of wrapping wires together to make electrical joint, and of taping joint.

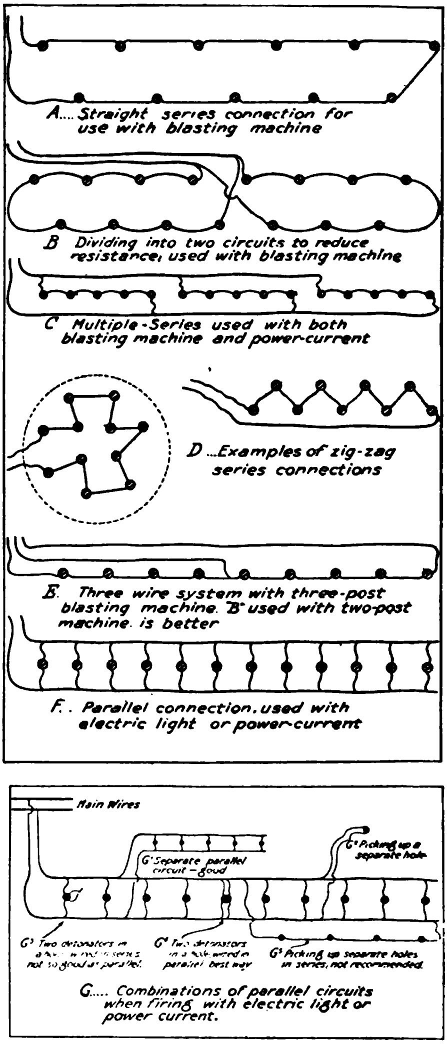
connections require current from an electric light or power plant. If your work is such that the charges cannot be connected in series or that parallel connections are desirable, it is well to communicate with an expert or authority on electricity for special suggestions and advice as to how best to fire your charges.

Current Required

In a bulletin of this size it is impossible to give a comprehensive statement of electric firing. But to give some idea, it can be stated that an electric blasting cap requires 1 to 1½ amperes to insure firing. This amount of current will fire one cap or many in a series. To force this amount of current through the wires requires a certain voltage, the amount depending on the size and length of all the wires, and on the joints. One bad or poorly wrapped joint will increase the resistance of the circuit more than several caps. The voltage of the current required to fire any circuit usually can be computed by an expert when the details of the wiring system are explained to him.

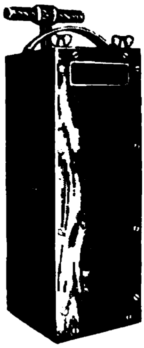
When charges are connected in parallel, instead of series, or in multiple series (see diagram C), each circuit requires 1 to 1½ amperes of current. That is, each cap requires 1 to 1½ amperes when connected in parallel. The voltage required, of course, depends on the resistance of the wires. A very much greater current than of 1 to 1½ amperes will do no harm; in fact it is desirable.

Electric blasting machines are constructed to give a sufficient amperage and voltage for


A.... Straight series connection for use with blasting machine
B Dividing into two circuits to reduce resistance, used with blasting machine
C Multiple-Series used with both blasting machine and power-current
D ...Examples of zig-zag series connections
E. Three wire system with three-post blasting machine. "B" used with two-post machine is better
F. . Parallel connection, used with electric light or power-current
Main Wires
G^1 Separate parallel circuit – good
G^2 Picking up a separate hole
G^3 Two detonators in a hole wired in series not so good as parallel.
G^4 Two detonators in a hole wired in parallel best way
G^5 Picking up separate holes in series, not recommended.
G..... Combinations of parallel circuits when firing with electric light or power current.

Ways of connecting up charges for electric firing.

firing properly the number of caps specified as the capacity of the machine when connected in a series. If too many caps, or more than usual wiring is connected to any machine, misfires will result. Other current can be used in place of that supplied by a machine, provided it has enough and not too much amperage and voltage. Too great a current will burn out wires without firing all the charges. Too little current sometimes will do the same, or it may do nothing. In emergencies dry cells or wet batteries can be used by skillful operators to fire a few charges, when great care is taken to have the wiring arranged for the purpose. Before attempting to fire charges with batteries of any kind, learn the amperage and voltage of their output and see that your shots come within their limits. The use of batteries is more expensive than the use of electric blasting machines.


Two post electric blasting machine—push down type.

Bare connections at the charges or back along the leading wire should be raised off the ground by stones, sticks or piles of dirt placed under insulated parts of the wires at each side of the splice. During a thunder storm, do not stand near any of the charges that have been connected. Avoid dragging the leading wire over bare or rough ground as much as possible, and particularly avoid kinking it. Be careful not to break or tear or scratch the insulating of any wires.

Do not attempt to fire through a long length of leading wire wound in a coil or on a reel. The induction, leakage or short circuit of current in the coil of wire causes the blasting machine to deliver a slow discharge, which is fatal to proper firing. Leading wire that is watersoaked or that is covered with mud will lose a considerable part of its current.

Misfires

Nearly half of the accidents noted each year in blasting operations are the result of attempting to examine misfires too soon. If misfires occur with fuse firing, stay away from the shot at least 2 hours. It is better to wait until the next day, for the spark may linger 24 hours and still cause an explosion. (See page 60.) Rock and stump misfires are to be avoided especially. When you are firing the charges electrically, you may approach the shot with entire safety as soon as the lead wire is disconnected from the blasting machine.

Misfires are due to the following named causes. The remedies for them are care in preparing the charges and in loading, the details of which are given in the proper chapters.

With cap and fuse firing, misfires are caused by having the end of fuse pulled back a little from the bottom of the cap, by crimping the fuse too tightly with a groove crimp and shutting off the spark, by damp or wet fuse, especially at the end of the cap, by defective cap, by the cap getting pulled out of the explosive, by kinked, damaged, broken or pinched fuse, by failure to light fuse. A great many misfires were never fired at all. With electric firing the reasons for misfires may be damaged wires in the hole, causing short circuits, defective caps, overloaded blasting machine, cap pulled out of explosive, bad wire connection at some point, or broken wire.

If you find after due time that for some reason the charge cannot be fired by lighting the old fuse or by sending current through the wires, you must deal with a real misfire.

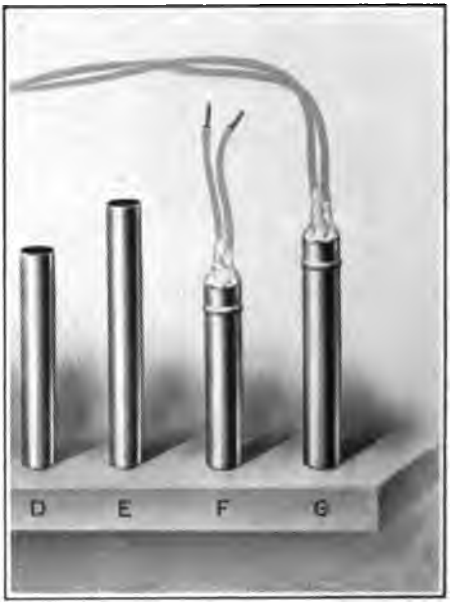
The best thing to do is to put in another, lighter charge in a new hole made 6 to 12 inches of the original one. The explosion of the new charge will explode

the old one. Never touch the tamping in the old hole unless you know just how deep it is, or how many inches of it there are above the charge. Once in a while the tamping may be dug out of a blockhole misfire. It seldom pays to do this in stump blasting, and never in ditching, or soil blasting. At best it is a dangerous operation. Mudcap charges can be opened and new primers inserted without danger or difficulty. This should be done by removing part of the mud at another point, and inserting a new cap and fuse, or electric blasting cap, as the case may be.

Cap (Detonators)

Blasting caps are little copper tubes closed at one end, 1½ to 2 inches long and something less than a quarter of an inch in diameter. At the bottom is placed several grains of a high explosive that is very powerful and exceedingly sensitive to heat, shock and friction. This high explosive usually is fulminate of mercury, but often is other material. They are packed in small tin boxes, open end up, usually 100 to the box.

The purpose of the blasting cap is to supply the shock and heat necessary to detonate the charge of dynamite or powder to be fired. If it were not for safety in handling blasting explosives, they all could be made as sensitive as the material in the caps. But such explosives would be impossible to handle without accident. In fact, it would be impossible to handle the little bit of explosive in the caps if it was not protected by the copper shells. Even at that caps must be kept free from jars and from heat and sparks to avoid premature explosion.

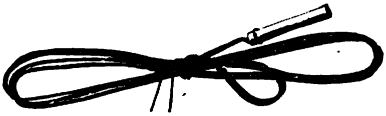


D and E are ordinary blasting caps; F and G are electric blasting caps often called fuzes.

The strength of caps is carefully regulated by the makers to fire the dynamites and powders on the market. The explosive material with which the caps are loaded is such as will deliver a shock and a degree of heat of the strength and violence required. The caps are numbered according to strength. All dynamites and powders used for agricultural blasting require at least a No. 6 cap. If they are chilled a little, but not frozen, they require No. 8. It is the part of wisdom to use No. 8 caps all the time if you can get them. They give you a margin of strength should moisture or other causes weaken them in storage.

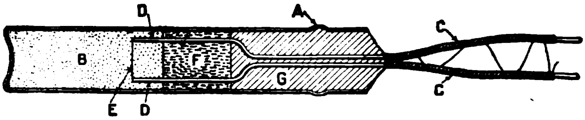
Blasting caps must be used with fuse. And before they are inserted in the stick of explosive they must be fixed to the fuse properly. (See pages 37 to 40.) It is the spark which travels down the fuse that fires the cap.

Electric blasting caps are made on the same principle as ordinary blasting caps. They have the copper tube, the explosive at the bottom, etc., but they differ in the way this explosive is fired. Instead of by a powder spark they are fired by a red-hot wire that is heated by an electric current.



Electric blasting cap or fuze.

Every electric blasting cap has fitted in it 2 small copper wires, which must be considered part of the cap. Down near the bottom of the cap is a delicate bridge of finer wire. The entire arrangement is held in adjustment and sealed by a casting of sulphur-like substance.



The interior construction of an electric blasting cap or fuze.

For fuse blasting you must use regular blasting caps, and for electric blasting you must use electric blasting caps. It is impossible to substitute one for the other. Never pull at the wires in an electric cap. It is dangerous and may loosen or throw out of adjustment the arrangement of wires inside. And never try to dig out the wires of an electric cap or to dig or to punch the explosive in the bottom of a blasting cap.

Fuse (Safety Fuse)

Fuse is used for firing black blasting powder and for firing dynamite and high explosive powders through the medium of a cap. It is made by enclosing within a covering a train of special black powder and an inflammable cotton string. The spark runs down this powder train.

Fuse as it comes in rolls.

The powder used in fuse is specially made for the purpose, is pulverized and is highly compressed by the covering of the fuse. The covering itself is made of varying materials, depending on the conditions under which the fuse is to be used. For dry work it is only enough to hold the powder in place and to keep the powder train from getting broken. For damp and wet work it is made waterproof by increasing the number of layers in the covering and by adding varnish, coal tar, as other waterproofing material.

Grades

There are many brands of fuse on the market. In buying fuse you must bear in mind the character of your work. For work that is entirely dry you can use ordinary cotton or hemp fuse with satisfaction, if it is large enough to fit a blasting cap snugly.

For work in damp ground, use a fuse in which the cotton or hemp is covered with one layer of waterproof tape or other material. This is called single-tape grade or may be known by brand name only. For work where the ground is wet, such as in stump and stone blasting in damp or wet weather, use a double-covered fuse—fuse that has two layers of tape or other material over the cotton

covering and waterproofing material added. For work where water covers the charges it is best to use fuse with three layers of tape or other material and full waterproofing. This is called triple-tape fuse or may have special brand names. When buying fuse for general farm work, it is well to get a waterproof grade, since it can be used for both wet and dry work.

Rate of Burning

Most reliable fuse burns about 2 feet per minute when in perfect condition. If it becomes damp, it burns much slower. Cases have been known where the spark smouldered in damp fuse for hours without traveling more than a few inches. Another source of uncertainty is where fuse has been pinched. It may take the spark a minute or an hour or a day to get past the pinched point.

When fuse is cold, it is hard and brittle, and may crack open when unrolled. If it gets too warm, its waterproofing material may penetrate to the powder train inside and ruin it; or the covering may first soften and then harden, in this condition breaking as though cold when unrolled. If grease is allowed on the cover it may combine with the waterproofing and ruin the powder inside.

Handling Explosives

Dynamites and powders in boxes can be hauled freely in spring wagons. You should see that no bolt heads or other metal parts project from the wagon boxes to strike the boxes of explosives. Sweep all dirt out of the wagon. Have the beds clean or covered with straw or blankets.

Go over your wagon and harness before you load dynamite to make sure they will not break down while you have the explosive aboard. Be sure you have the hitching straps or tie-ropes along, and do not leave the horses standing without tieing them securely. Break no colts while hauling explosives. If you use a motor, stop it and set the brake tight before you leave the load. In driving through a town stay away from dangerous crossings.

Keep the sticks of explosive in their original boxes until you are ready to use them. Don't have them around loose. In carrying them to the field, use a wood basket or a box and not a metal bucket. Always protect explosives from all possibility of being reached by falling sparks or from match heads or other source of fire. Rain, hot sun and the like must be kept away from explosives. Use care to lay sticks or set the boxes or baskets containing explosives where they will not fall down, be blown over by wind or knocked over by careless people or by animals. Cattle will eat sticks of dynamite, or powder, because of their sweet and salty taste. The explosive will make them sick, sometimes kill them.

Since nitroglycerin often will cause headache when absorbed through the skin it is best to wear gloves when handling the sticks. For this same reason some people punch holes for caps in the sticks with a piece of wood rather than with the handle of the cap crimper.

Caps should not be carried in the same basket or box as explosive, but should be carried separately. Take only enough along to do the work in view and carry them in the tin boxes they come in. Many serious accidents have been caused by blasters having loose caps in their pockets during work or afterwards. Sooner or later a chance jar is likely to set them off. When several caps have been taken out of the little tin box in which they come the rest will be loose and will rattle about. This should be stopped by filling up the empty space with paper.

The handling of caps is not dangerous provided you do it intelligently and with care. *Keep them safe from any jars or heat.* You can sometimes do

many foolish things with dynamite and powder without serious results to yourself, but not with caps. Letting a cap fall to the ground or floor likely will cause it to explode. For this reason you should keep the caps and explosives apart, in hauling, storing, and handling, bringing them together only at the last minute before you prepare the charge to be loaded in the hole. One cap can produce an explosion powerful enough to tear your hands off.

Handling

Electric blasting caps must be handled with the same care as regular blasting caps. All caps must be protected from dampness during handling. No trouble will be experienced if you use common sense at every turn, but thoughtlessness and carelessness in the handling of explosives will cause disaster. Bear in mind that when an accident happens with an explosive there is no time to save yourself, and no afterthought will prevent serious injury to you. Forethought is the thing with explosives. In an explosive you are handling an enormous strength. The fact that it occupies small bulk now should not interfere with your imagining it as an enormous engine with power enough to crush you easily, but under entire control if you do your part right.

Storing Explosives and Supplies

The storing of dynamites and powders on farms offers no serious problems, though it may call for some shifting of arrangements to meet proper requirements. The explosive must be kept dry. They should be kept cool. This means that any ordinary temperature of the air is all right, except that in hot weather the room where the explosive is kept should not get warmer than 80 or 90 degrees. If it is properly ventilated day and night it will not. Probably the best common storage place for explosive is in an outbuilding under the floor of which the air circulates freely and with a ceiling between the room and the roof. It should be strong, and should be provided with a lock. A responsible person should have charge of the key at all times.

The explosive should not be kept in a garret, because the hot sun beating down on a roof will raise the temperature under the roof away past the 100 degree mark.

Dampness is injurious to explosives, as noted on page 48, and dynamites and powders must be kept where moist air will not surround them. The ideal storage would be fireproof, but since this is out of the question on the average farm, the best that can be done in that respect is to guard against fire. It is well to make sure that the explosive is out of reach of any stray or malicious bullet that might be fired into it.

Look to your insurance policies and see whether they provide against the storage of explosives in any of your buildings. Store the explosive in a building not covered by the insurance.

Magazines

Where large quantities of explosives are to be stored as a regular thing, or for any length of time, it is advisable to consult the makers of explosives or others experienced in their handling in regard to the location and construction of a magazine. A magazine can be set up cheaply and can be made fireproof, bullet proof, thief proof, well ventilated, dry and safe in every way. It should be built of brick. Any explosive maker will furnish plans without charge. In any case explosives should be stored at least 50 yards away from any other buildings and from roads or railroads.

Caps

Blasting caps of any kind must not be stored with dynamite or powder. Fuse is not explosive and can be stored with dynamite or powder. Blasting caps are even more subject to damage by moisture than explosive and must be stored accordingly. Caps must not be allowed to become heated.

Deterioration

A statement of the ways in which explosive deteriorates will help in selecting a proper storage place for it. In temperatures higher than 80 degrees troubles may begin. Long continued temperatures of 90 to 100 degrees may cause the nitroglycerin to leak out of the absorbing material and to gather inside the wrapping on the lower side of the sticks, or may even cause it to leak out of the wrappings through the boxes and to the floor.

Strict watch should be kept of the sticks and the boxes to catch any such condition. If leakage occurs, turn the explosive over and reduce the temperature. Burn the empty boxes one or two at a time out away from buildings, and scrub the floor where the leakage occurred with a strong solution of sal soda. This will decompose the nitroglycerin. If it becomes necessary to destroy a little explosive without detonating it, the job can be done by immersing it until dissolved in such a solution, stirring it gently with a wood paddle.

If the sticks feel smeary it is possible they are leaking. The test is to lay them on white paper for a little while. If they are leaking they will stain the paper, otherwise not.

At a temperature of 105 degrees nitroglycerin explosives will lose 10% of their strength in a few days by evaporation. Repeated freezing and thawing is bad for explosives, especially if the thawing is rapid. Slow thawing will not damage them much. After explosive once is frozen and thawed, it will freeze much easier again.

When stored for many months explosives are liable to decomposition of some of their elements, especially if they get damp or too warm. One of the marks of this is greenish stains inside the stick wrappings. No length of time can be stated for the keeping of explosives, because it practically all depends on conditions. Under favorable conditions most dynamites and powders will remain in good shape for years. Again, a month of improper storage will ruin them and make them dangerous to handle. They develop troubles sooner in the light than in the dark.

Deteriorated explosives are likely to be dangerous—far more so than normal explosive. Keep watch over what you have in stock. Maintain proper conditions as far as possible, but if they show troubles do not hesitate to condemn them.

Shipping Explosives

The shipping of high explosives is controlled by the Interstate Commerce Commission, and the rules and regulations are very strict and rigid. Most of them are embodied in an Act of Congress of March 4, 1909, and violations are punishable with fines of not more than $2,000, or imprisonment for not more than eighteen months, or both. The person making the shipment is responsible.

A copy of the rules and regulations can be secured from the Bureau of Explosives, Underwood Building, New York City, or can be read at any freight station where there is an agent.

The rules provide that no explosives (other than certain exceptions named) shall be carried on any train, boat, trolley, or other vehicle carrying passengers

for hire, and that no explosives under deceptive or false markings or understanding shall be delivered to a common carrier; and further, that all other regulations shall be complied with.

In shipping by railroad no caps or detonators of any kind can be sent in the same car with explosives. In practice the railroads usually send them by another train, which works out to be another day in the cases of nearly all shipments. This is responsible for some delay in delivery of explosive shipments. Do not expect to have explosives come through as quickly as you would other freight.

Explosives cannot be shipped by express or by mail, but are sent by freight, the same as groceries or dry goods. The railroad company is required to place the packages in a certain way inside the car and to brace them with lumber. In case of car-lot shipments the shipper must furnish this lumber and do the bracing.

The regulations provide that railroads must have 24 hours' notice of shipment of explosives, *and that shipments must be removed from the receiving station within 24 hours of their arrival there.* The packages must be plainly stenciled with the name of shipper and consignee, and bills of lading must conform with certain specifications.

Empty boxes which once have contained explosives must never again be used for shipments of any kind. Farmers who have attempted to ship vegetables or other farm products in such boxes have unwittingly gotten themselves into trouble on account of this regulation more than once.

Danger and Safety

Modern explosives have been developed to the point where they need not be feared by anyone who handles them intelligently. Speaking in a comparative way, they may be used with no greater dangers than there is in the using of horses, mowers, traction engines, sawmills, or other farm equipment, or than there is in using shotguns or rifles.

The general use of explosives on farms is so new that many people distrust them more because of their newness than from a clear understanding of any actual dangers their use may hold. A review of what the dangers are may help users of explosives to avoid them, and may help to build up the reader's belief in the *safety* of explosives.

There is some danger in the handling and transporting of explosives, but it depends very largely on the exposure of the dynamite or powder to heat, flame, sparks, blows and friction. The directions say to keep explosives dry, to keep them at a temperature less than 90 or 100 degrees F., to keep them safe from sparks, and to avoid blows and shocks. If these directions are followed there will be few accidents.

Probably the most common cause of accidents with explosives lies in violation of some of these primary rules while thawing frozen sticks of dynamite or powder. Freezing makes the high explosive less sensitive to the simple direct shock of a blasting cap, unaccompanied, as it is, by any friction. But at the same time freezing makes the explosive more sensitive to friction in any form.

For this reason, though a frozen stick of dynamite cannot be fired properly by a blasting cap, it is very likely to be fired prematurely by a chance light blow from any object touching it, by your slitting the wrapping paper with a knife, by breaking the stick in two, or by attempting to punch a hole into it to insert a cap. (These operations are entirely safe when the explosive is normal.) If the stick is dipped in warm water or exposed to steam, or is laid on anything which is warmer than about 125 degrees, free nitroglycerin likely will leak out

and fall in drops. And one drop of nitroglycerin falling only a few inches may be exploded itself and may explode all dynamite that is near it.

Throughout the entire course of handling the explosive, from the freight station to the hole in the stone or the ground, you should remember the five cautions which will be repeated: Keep it dry, keep it cool, keep it away from sparks and flame, and keep it safe from blows and friction. Be careful—as careful as you would in driving a big automobile or a traction engine. Then you will be secure from any accidents, and explosives will be entirely safe to handle.

INDEX

Page
Accidents 52, 53
Ammonia explosives 48
Amount of explosives required 30, 31
Augers, Soil 33
Blast ditch, How to 20, 21, 32
Blasting machine 35, 54, 57
Blasting, Possibilities and limits of 14, 15
Boxes of explosives 49
Breaking sticks of explosives 41, 42
Burning of explosives 45
Buying explosives 49
Capacity of ditch 9, 19
Caps and fuse, Putting together 37, 39
Caps, Blasting 51, 59
Caps, Electric blasting 59, 60
Caps, Position in sticks 39, 40, 41, 44
Carrying explosives 36, 61, 62
Charge, What it is 36, 45
Chilled explosive 48, 51
Cold weather blasting 24, 27, 48, 51
Conditions demanding drainage 6
Connections, Wire 55, 56, 57
Cost of ditch 9
Cost of explosives 49
Crimping caps 38, 39, 41
Current required to fire charges 67
Cutting sides of ditch 3, 11, 25
Cutting sticks of explosives 41, 42
Danger 64
Depth for charges 28
Depth of ditch 16, 18, 28
Deterioration of explosives 63
Detonation 50
Detonators 51, 59
Difference in explosives 46, 49
Ditches, Blasting of 20
Ditches, Example of blasted 29
Ditches, Methods of making 12, 15
Ditches, Size of 16, 18, 19, 28
Ditches, When needed 6
Draining 6, 9, 10, 12
Dry ground 11, 22, 25

Page
Dynamite, General properties 49
Dynamite, Grades and types of 21, 25, 46, 47, 50
Dynamite, Kinds recommended 22, 25, 50
Dynamite, Low freezing 48
Dynamite, Names and brands of 46, 50
Dynamite, Removing wrappings from sticks of 41, 42
Dynamite to use 22, 25, 50
Electric blasting caps 44, 51, 55, 59, 60
Electric blasting caps inserted in sticks 40, 44
Electric firing advantages 54
Electric firing, Wiring required for 54, 55
End priming 41, 44
Essentials of good ditching 9
Explosive, Ingredients 46
Explosive, Required amount of 30
Explosive, Required per charge 31
Explosive, Removing paper from sticks of 41, 42
Explosives, Frozen 48, 49, 51
Explosives, Low freezing 48
Explosives, Names of 46, 47
Explosives, Properties of 46, 49
Explosives, Quickness of 47
Explosives recommended 50
Explosives, Strength of 47, 48
Explosive, To use 22, 25, 50
Finishing ditch 34
Firing ditch blasts 21
Firing electric 21, 53
Freezing of explosives 48, 49, 51
Fumes 49
Fuse and caps, Putting together 37, 39
Fuse, Cutting of 37, 38
Fuse, Description of 37, 38, 41, 60
Fuse fastening to sticks of explosive 40, 41, 45
Fuse length 37
Fuse lighting 44, 53
Fuse safety 60
Fuzes 44, 51, 55, 59, 60
Fuzes, Priming with 40, 44
Gases, Nature and volume of 47, 49
Grade of ditch 9, 16, 17, 18
Grass, Blasting ditch through 3, 11, 25
Gravel, Making holes in 27

CLEARING LAND OF STUMPS

By J. E. MATTERN

Published by
The Institute of Makers of Explosives
103 Park Avenue, New York City
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HERCULES POWDER CO.

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INTRODUCTORY

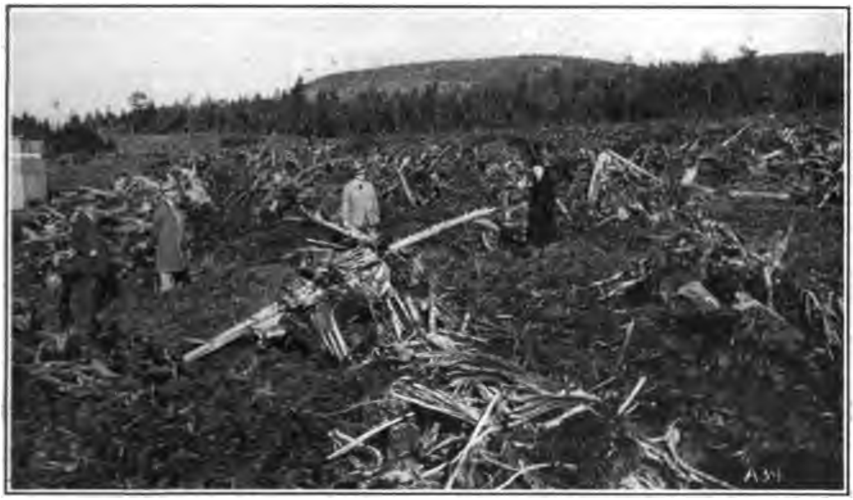
THIS bulletin is published by The Institute of Makers of Explosives. The aim is to give the united conclusions and the sum of the experiences to date of nearly all makers of explosives and of farmers who have dealt successfully with the problem of stumps in fields, roads or any land to be cleaned up.

The material has been assembled so any phase of it will be available easily and quickly. Conflicts of opinion have been eliminated in favor of known facts and formulæ. The bulletin is offered as a manual or handbook for farmers, home and road builders, contractors, park makers and others who remove stumps from land, and as a textbook for students of agriculture.

Readers will find that the recommendations are impartial, and that the suggestions on that part of the work which can be done best with explosives are particularly complete.

To Clear or not to Clear

A "stump" may be defined as any kind of a growth that obstructs land, whether it is the butt of a cut tree, a tall snag, a living tree or a bunch of sprouts or brush. From the viewpoint of a farmer it is a stump if it obstructs the plowing and other tillage of the land.



The sort of wreckage practically perfect stump blasting should give. The pieces are shattered so they are easy to handle and so they burn well.

When Not to Clear

Before deciding to clear land, the owner should consider several features of the matter well. The reckless slaughtering of the timber has left in stumps many thousands of acres of land which is not fit for cultivation and that should go back into timber. Such land, of course, should not be cleared. On the other hand it is folly to permit brush land which has good soil to lie idle when a hundred years will not develop profitable timber on it.

Much land that is in woods now should be left so, for timber and for fuel. Every farm should have its timber tract, where the forest is conserved in a way to make it permanent. To cut young growth that will make good timber in a reasonable time is a mistake, no matter how good the soil is. Remember, too, the wind-break value of a piece of woods adjoining farm land, and consider the effect on land you now farm of taking away the protection afforded.

Do not clear land where the soil is too stony to be cultivated to advantage, or land that is exceptionally steep or incurably swampy. Do not clear when the profits would not justify the clearing. And do not clear when you can buy equally good improved land for less than the cost of clearing.

There is a certain sentimental satisfaction in clearing and cleaning up one's own place, connecting fields and improving it generally, even though such improving will not add greatly to the actual money income from the crops. This will have a bearing in some instances.

But hard-headed judgment should not be swayed too much by sentiment, for there are a good many thousands of acres that have been cleared and now are parts of farms, which it would be wise and profitable to plant to forest again. Lay out your clearing carefully. Include no corners, gullies or steep places you will afterwards neglect. And make sure your field is rightly placed in relation to the rest of the farm.

A fertile looking field which could not possibly pay a net profit of more than half what it should so long as the stumps remain as they are. Two or three years' gain in crops, or less, would pay for the blasting out of the stumps.

About new clearing there may be some question, but about taking out stumps in good cultivated land there can be none. There are stumps in fields and along fences, roads, hedges and on home grounds. There are pastures that are pastures and not wheat fields or orchards because cultivation among the stumps is too inconvenient. There are old fruit trees and old shade trees that are diseased and a menace. All these should come out, and the quicker they come out the better.

Worth little even as pasture land, never rising in value, but potentially worth $100 an acre as soon as it is cleared. This is the sort of valley floor that makes splendid fields of oats, corn, alfalfa and other hay.

The Profit and Loss Account of Stumps

The man who is taking up the farming of cut-over land knows that he cannot do much until the stumps are removed. But lest he be tempted to permit some of them to remain in the cultivated fields, as many men on older farms are doing, it is well to point out some of the losses which stumps cause and some of the gain which their removal brings.

Appearance

No farm is well ordered when its fields are foul, and no farmer commands the respect of his neighbors when stumps are crowding out his crops. The loss in self-respect probably is even more serious.

In farming stumpy fields a man does not have that sense of having done his best, which is half the battle for success.

Tool breakage is another source of loss caused by stumps. Plows and furrows are broken, mowing machines and binders are both broken and racked and in some cases the use of machinery is prevented. Heavy engine tools cannot be used at all where there are roots in the ground.

Greater speed and ease of cultivation is a prime reason for taking out stumps. The use of gang plows, wide harrows and other modern labor- and time-saving equipment and methods is practical and economical only on land that is clean, both above and below the surface. And such use is becoming of more and more importance, as farm wages go higher and labor becomes scarcer.

When the stumps are as thick as the hay piles or the shocks of wheat or oats or corn there is something the matter with the farm system. They are boarders who never pay any bills.

The injury to horses often is much greater from a money standpoint. Spavins and sprains result from jerks against roots. Mares are caused to slink foals, young horses are made balky. The danger of injury to men is by no means absent. The kick of plow handles rupture many men, and every year sees its quota of broken arms and legs among farmers who try to plow, cultivate or mow among stumps.

Weed spread is a thing that must be charged up to stumps. They grow about the stumps, mature seed and pollute the whole farm.

Just as the presence of stumps tends to lower the value of land and to keep it down, clearing off the stumps will raise it and keep it on the increase. Once start to clearing away the stumps on your place and the neighbors and people who pass on the roads will take it for granted that the place is a paying proposition, worth developing. If you want to sell it, there is no surer way of adding a few hundred or a few thousand dollars to the selling price. To hold stump land for increase in value is a mistake. *Clear it up and force the increase.*

Increased Production

The actual gain in crops to be secured by the removal of stumps can be measured by the proportion of the total ground that they occupy. For instance, in many cases a stump takes up a square rod of ground. In measuring the value of the removal of stumps, the gain in crops and in speed and ease of working the ground should be compared, not with the total value of the crop, but with the net profit before stumps are removed. Thus, if a 25-bushel crop of wheat costs 20 bushels to grow, the addition of 5 bushels to the yield will increase the net profit 100 per cent. Two dozen stumps to the acre may occupy such a large part of the acre that their removal will double the net profit.

This is the typical appearance of much land that is very fertile and which would pay handsomely if in alfalfa or fruit. (Near Linville Falls, N. C.)

The clearing up of land can be made to mean something more than the financial profit it brings, for when properly handled it well can be made one of the links that hold the boys to the farm. Once a boy has helped to develop a property in a way that he enjoys he will remember that place as home as long as he lives. And boys will be enthusiastic over the clearing operations, with the necessary planning for new fields, the blasting and stump pulling, and the burning afterwards, if the work is managed along some of the newer lines which take out the drudgery.

The Essentials of Good Stump Removing

Before settling on a plan for removing stumps, it is well to have clearly before you just what is required.

The stumps must come out entirely, or at least deep enough so that roots never will catch plows or other implements. Stumps with roots must be disposed of as profitably as possible, used if possible, or burned cheaply. They often can be sold or used at home for firewood of some kind, or sold for extract purposes. Failing this, they must be burned on the ground with as little damage to the soil as possible. In any case they must be broken into pieces small enough to handle by hand, unless derricks and power are to be used to handle them.

When all the trees of a woods-lot are cut down, the ground seldom is protected from animals and so treated as to grow a new piece of forest. But it should either be put in forest or cleaned up and farmed. The green stumps should be left stand a season, then should be blasted out with about four charges each. They are almost impossible to pull economically.

The total money expense of the clearing project must be within the capital available for the purpose, and the labor and time required must not exceed the supply. The condition in which the ground is left also is important. The holes should be shallow, and the less littering and tearing up of the surface there is, the better. The work usually should be finished in time for planting a crop in the spring, for the loss of a year's time costs money.

These are the things which should be included in the plans for clearing.

Nature of Stumps and Conditions Affecting Their Removal

There are about 500 different varieties of trees which make stumps in America, and it is not advisable to classify them all in this bulletin. What is of value is to review the nature of their roots.

There are three general types of roots—lateral roots, semi-tap roots and tap roots. (See cuts, pages 24 to 26.) Some varieties of trees always grow in one way; other varieties grow in either of two ways, depending on soil conditions. The stumps of some trees rot fast, while others are very durable. Some roots die when the trees are cut; others throw up sprouts. The wood of some roots is tough and can be twisted a great deal without breaking; of other varieties it is brittle and will break off when bent or jerked.

Root Growth

Typical tap-root stumps are long-leaf southern pine, hickory and black gum. Some of these trees grow a root that is almost as big as the trunk, extending straight down into the ground. Others have slender roots. Sometimes these tap-roots send out lateral roots of some size, but in other cases the laterals are limited to hundreds of short, hair-like rootlets growing from the main tap-root. The tap-root itself sometimes splits at a point several feet underground into several smaller roots, all of them continuing to grow nearly straight down.

Typical lateral root stumps are elms, soft maples, locust, dogwood, elder, hemlock and some cypress. The roots of these trees grow in all directions from the trunk near the surface of the ground. Working the ground close about such stumps is next to impossible.

The largest class of stumps is the semi-tap-root class. Belonging to this class are white pine, poplar, chestnut, ash, walnut, red, black, pin and other oaks, persimmon and sassafras. Stumps of this class are harder to remove than either of the other two types, because the roots generally are big and strong and grow in all directions, some along the surface, others almost straight down and still others between.

Wonderfully productive meadows, for timothy, alfalfa or other grass, can be made by cleaning up and draining stump flats. This land was a tangle of old logs and stumps a few months before the picture was taken. (Michigan Land & Lumber Company.)

What may be classed as a fourth division is composed of the root clusters of sprouts and bushes of almost any sort of trees, whose growth has not yet taken the characteristic form. Brush of willow, elder, maple, chestnut, hickory, oak and witchhazel may be named. The roots are very firmly anchored in the ground for a distance of three or four feet in all directions.

The nature of the soil and the height of the water-table in it have much to do with determining the root growth. A hemlock tree, for instance, will send its roots down till they almost take on the nature of the semi-tap-root class in soil that is loose, free from stones and *dry*. The same tree would have few roots deeper in the ground than 6 inches where the soil is hard and the water-table near the surface. The root growth of other varieties of trees is affected by water and soil in the same way. A tree that grows on a steep hillside probably will have heavier roots on the sides than on the downhill and uphill grades.

A glimpse of primeval forest and of primeval stumps, the like of which few farmers meet in the eastern part of the country any more. Such land is expensive to clear but it is exceptionally fertile in most cases.

Rotting

Some stumps are durable and others will rot very fast. White pine, Norway pine, locust and cedar stumps will last fifty years without decaying enough to make much difference in the work of their removal. Chestnut, white oak and catalpa are nearly as durable. The other oaks, poplar, ash, hemlock, hickory and gum rot so fast that in a few years a team of horses can roll out stumps of considerable size.

It should be understood that during the first season, after any variety of tree is cut and the stump and roots die, the bark and soft outer layer of wood rots away, making the roots loose in their earth channels. It is the inner or mature wood which lasts.

Sprouting

Another characteristic of stumps which is of importance in clearing plans is their sprouting. None of the pine stumps will sprout when a tree is cut, but nearly all the hardwood stumps will do so. Chestnut is a great sprouter. A stump that does not sprout is not getting any worse as time passes, but one that does sprout is likely to be harder to take out each succeeding season.

Water

All kinds of stumps pull easier when the ground is wet than when dry. Explosives are more efficient in wet ground than in dry. Pulling machinery ordinarily is handicapped in very wet ground, because of the lack of firm footing.

The nature of the soil, whether light or heavy, has a considerable effect on the way stumps come out of the ground. Naturally a loose, fluffy sand will hold the roots less than heavy clay. Pulling them out

This clump of trees was blasted out (not cut down.) The stumps are torn out better than they might have been without the weight of the tops to pull them over.

of sand, therefore, is much easier than out of heavy soil. On the other hand, light soil will not confine the gases of explosives nearly as well as clay. In sand the greater ease of tearing the roots loose is more than offset by the lowered efficiency of the blast.

Kinds of Soil

The foregoing principles should be of more actual service to land clearers than a description of the conditions in different sections. If your stumps are Southern long-leaf pine, you know they will not sprout, and are of the tap-root class. If they are white pine of Michigan or Maine, you know they are of the semi-tap-root class, that they will not sprout and that they

This picture shows what they look like when down. The roots are torn out better than they would have been without the tops to pull them over. Note how easily they can be sawed or chopped.

When stumps are lifted by frost as much as some of these, they often can be pulled economically. They should be split up afterwards with light charges of explosive placed in auger holes or between roots, under a mudcap.

probably will outlast you if you do not move them. In case of a locust stump in Oklahoma, you know that you have a lateral root stump to deal with, that will sprout and that will last as long as the white pine. These illustrations serve to point out how every reader can classify his own stumps as to facts about them that are important from the clearing standpoint.

Methods of Clearing Land of Stumps

A half-dozen methods of removing stumps are more or less well developed throughout the country. Everyone who clears land, whether it is only the removal of stumps from cultivated fields or the clearing up of logged-off areas, should study the different systems in order to decide which of them is best under any particular conditions. No one method is best all the time, and in nearly every case a combination of various means will be found most effective.

Lists of Methods

Digging out the stumps by hand.

Pulling the stumps. The pulling may be done with horses or machines. The pull may be direct, or may be doubled or tripled in force by means of blocks and cable or rope. If with machines, it may be with a traction engine hauling direct, a donkey engine hauling by means of a drum and cable, a capstan puller run by horse power or man power, or a tripod puller which lifts the stumps straight up. (See pages 15 to 21.)

Burning the stumps. The old-fashioned practice was to start a fire alongside a stump and keep it going till the stump was consumed. Charpit burning consists of keeping an intensely hot but small fire about the base of a stump under a covering of earth. Another method is to bore auger holes through the stump or part way through, to form draft holes and flues. A favorite method in some sections is to burn out the roots with a gasoline torch to a depth below the plow line.

Finally, there is the use of explosives to blast out the stumps.

Combinations of methods very often are valuable, and are recommended at proper points.

Stump Disposal

The land clearer must remember the necessity of disposing of stumps after they are out of the ground. It is expensive and difficult to haul or burn whole stumps. Several hundreds of pounds of earth nearly always stick to the roots of big stumps taken out unbroken. For this reason wherever it is possible to do so the stumps should be broken into pieces small enough to be handled easily before the job is considered done. There is no comparing the cost of burning stumps, when they have to be piled by means of a derrick, with the cost when they can be handled by hand.

Choice of a Method

Green vs. Old Stumps

Whether to remove stumps when they are green or to let them decay a year or more is a problem to be decided by your plans and the uses to which you will put the land. Newly cut-over land is clean. It has few weeds and no sprouts. In one season it will not develop much of this growth, but in two or more seasons it will, and will be very much harder to clear than it would have been the first year.

The stumps are hard to take out while they are green. It costs much more to do the work then than a year or more later, after the bark and sap-wood has rotted from the roots.

But it costs money to miss crops, too, and if you are ready to put the ground to work at once, it is folly to wait for the stumps to rot. To wait from summer till the following spring is not a bad idea, for that loses little or no time, and starts the rotting process which makes removal easier and cheaper.

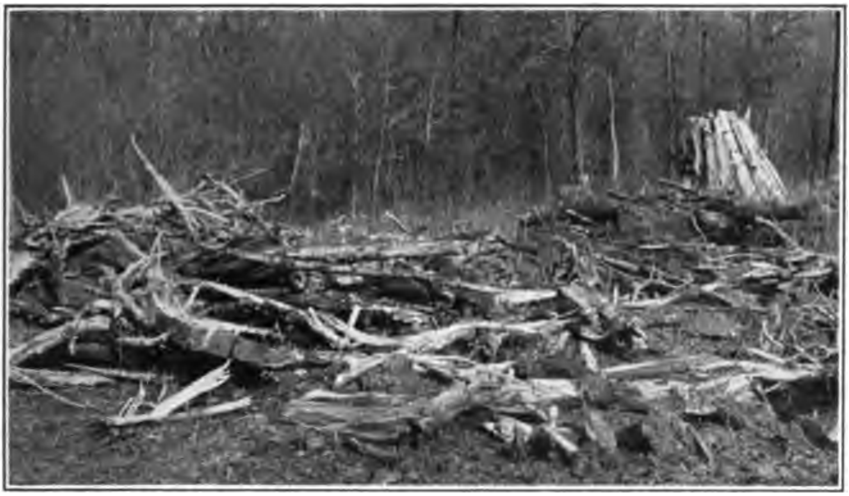
Speaking in general of pulling and blasting, pulling the stumps probably is better and cheaper when the stumps are very small, and blasting when they are large. Where a large number of big stumps are to be removed a combination of the two methods is advisable.

Pulling and Blasting

When stumps are small or numerous they can be pulled by a team of horses hitched direct, by a capstan puller, traction engine or donkey engine, with ease and speed. The pulled stumps can be handled by hand directly, and disposed of without trouble. The same is true to a lesser degree when larger stumps grow small and shallow roots, which require but little power to lift and move.

For stumps larger than 3 to 5 inches, explosives can be used alone effectively and economically, though there are important considerations which modify such a rule. One of them is that of soil. Explosives work more effectively in heavy, tight soil, such as moist clay, than in dry sand. Therefore, in dry, light soil it often is cheaper to pull all the stumps not too large to handle without breaking up, while in heavy soil it usually is cheaper to pull only very small stumps that will come out easily, and to use explosives, alone or in combination, for everything larger.

Old, well-decayed stumps too big to handle should be removed with explosives alone. Small green stumps may be blasted out clean, roots and all, but large green stumps nearly always require a combination of methods, as, for instance, blasting and team pulling, or pulling with a capstan puller. The cost of explosives often can be cut down by making use of such a combination of methods. A heavy team, or other means of pulling, will take out roots after the ground has been loosened with explosives.



This picture shows how the roots of large green stumps can be broken up for handling by proper blasting of the stumps. There is little reason in clearing a piece of land twice of the same stumps—once to free them from their beds and again to dispose of them—by pulling—when the job can be completed with half the trouble and expense by blasting and hand piling.

Tap-root stumps larger than your arm should be blasted. Tap-root stumps cannot be pulled to advantage, though when very small they can be broken off by a side pull. Where land is swampy on the surface, and roots consequently lie shallow, a heavy team often can rip out stumps by direct pull, even up to fifteen inches in diameter.

Large stumps that are pulled may be broken up afterward with small charges of explosives placed in auger holes, but in general it may be stated that large stumps should be blasted first.

The folly of pulling out stumps that are big, and then spending as much money in getting rid of them as it costs to pull them, will be plain to any one. They can be disposed of at a fraction of the cost when they are well broken up.

Capstan Puller

A more detailed consideration of the pulling of stumps probably is desirable. Pullers are most successful in the loose jack pine land of the North and the similar pine land in the South, and in clearing hardwood cut-over land where nearly all the stumps are small. They are particularly serviceable where the stumps stand close together, measure 3 to 6 inches and have root systems which do not bring up much dirt. Under such conditions a stump puller is a good investment, especially where there is plenty of man and horse labor available at low cost.

But it does not pay to buy a machine for a small acreage of clearing—only where a considerable quantity of clearing is to be done. In vicinities where the soil is light and there are many stumps on newly cut-over land, several farmers should co-operate in the purchase of a stump puller and should help one another to use it.

A stump puller works to least advantage under clay soil conditions. Another factor is the water in the ground. The ground must be fairly dry when the machine is used, even though the stumps require harder pulls then than when the ground is water-soaked. In mud, horses soon become mired deeply. Pulling of stumps must be done in the summer or fall. Of course, they cannot be pulled when the ground is frozen.

Two large hardwood trees which stood close together and were blasted out at one shot, without cutting down. About eight charges were used. The cavity in the ground is small and the soil is free from tight roots.

A capstan puller can be used on a moderately steep hill, though the cost of pulling the stumps from such ground will be greater than from level land. Whenever it is desired to use a stump puller, have explosive materials on hand to blow out or to split and loosen any stump larger than about 5 inches.

Donkey Engine

A donkey engine outfit especially designed for stump pulling can be used effectively and with success. It makes an expensive outfit, however, and unless there are several hundred acres of clearing to do, consideration of it may be dropped. In the case of very large acreage, it is the logical form of capstan puller to use.

Traction Engine

A traction engine, pulling stumps direct, is a very effective means of getting stumps out. In fact, when such an engine is available it is doubtful if the purchase of any other machine ought to be considered. Both traction and donkey engine pulling is subject to the same limitations as pulling by any other means, and should be confined to such work as they can do to advantage in comparison with explosives or other methods.

The detailed consideration of the blasting of stumps may be short and to the point. The use of explosives reduces the labor of land clearing greatly. One or two men with explosives can do the work of a large crew with pullers or fire.

When to Blast

The stumps can be blasted out clean. Thousands and thousands of acres of stump land are cleared completely every year with explosives alone. While the use of some means of pulling in connection with explosives undoubtedly cuts down the cost on a large tract of clearing, the added ease and speed of the work of explosives alone is considered by many people to offset this economy. For small tracts or a few stumps it is foolish to provide pulling facilities. Do the work with explosives.

The blasting splits the stumps into pieces easy to handle, and to sell or burn. When it is not desired to blast stumps out clean, the charges can be kept down and the stumps split and the dirt loosened and thrown away from the roots. The blasting does the work in a short time.

The investment of money is kept down when explosives alone are used. There is no machinery or equipment left on your hands after the clearing is done. Yet the best use of stump pullers and of explosives is mainly distinct and different, and they should be considered, not in competition, but in combination. A good team and a supply of explosive material is a winning combination nearly every time, and explosives are bound to play an important part in nearly every land-clearing operation.

Digging out stumps is practicable under certain exceptional circumstances. If you cannot get explosives and if you have men who are doing nothing, they may be put to digging out stumps; but if wages have to be paid, such clearing is bound to cost four or five times as much as when the work is done by better methods.

This pine stump is burning freely, and likely will be consumed if it receives some attention. The roots were bared of dirt and the stump was split by a light charge of explosive. When stumps can be left to dry for a couple of months after such splitting, they will burn very well, though pine stumps can be burned immediately afterward with a little coaxing.

Big stumps such as this can be blasted out electrically much easier and better than with charges fired with fuse.

Burning by charpitting is a practicable and cheap method of getting rid of soft wood stumps of large size and in heavy or clay soil when the weather is dry for two months or more at a time. It is not successful in lighter soils. It is costly when labor must be hired for the purpose, and wastes time. This method of removing stumps is chiefly valuable for settlers of logged-off or cut-over land who must fight their way through with little or no money.

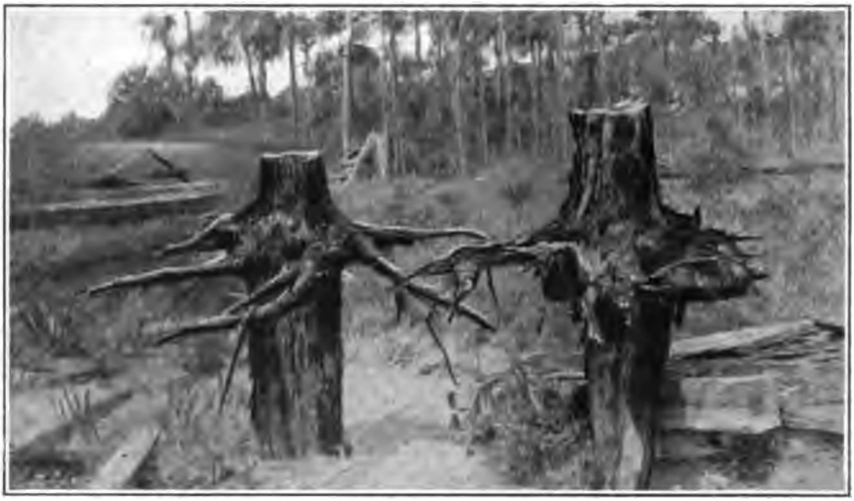
When to Burn

Burning by means of auger holes, and the use of oil, are freak methods not suitable for general use. They should not be attempted when the clearing operation is seriously intended to be economical. Burning with a torch of some kind is effective, but expensive.

Detailed Directions for Clearing Land of Stumps

Digging Out Stumps

If you dig right down after the roots, trenching to bare them, cutting them off with an axe first at the sides and then underneath, the stumps can be rolled out as though they were pulled. The cost is high.



Typical tap-root stumps, with the dirt washed away. To blast them out the charge must be located against the big root, four or five feet below the surface of the ground. Two charges to each root are better than one, though either loading will cut the root off successfully.

Trench about Trees

If possible to know beforehand that you must dig stumps out, do it before the trees are cut. Dig a trench about them, taking away the support, and cut the lateral roots, and then let the wind and water finish the job. The water in the trench will soften the subsoil. The best time of year to do it is in the spring, when the wind is strong and the ground is loose.

Burning Out Stumps

Charpitting

Charpitting is perhaps the best method of burning stumps. The fire is kept burning at the base of the stump till it burns entirely through, and till the top is consumed as it settles down and the roots are eaten out to a proper depth below the surface of the ground. The fire is confined by a covering of earth.

Charpitting is effective only when heavy grounds can be secured to cover the fire. Sand, loam or other light soil cannot be used for the purpose successfully.

Conditions

The stumps should be reasonably dry, and the weather should be dry during the burning process, which takes two to six weeks. Light showers are not objectionable, but heavy, settled rains cause failure. Pine stumps burn best, because of the pitchy nature of the sap remaining. Any other soft wood can be burned this way. The successful burning out of hardwoods requires favorable conditions in all respects, and is rather doubtful in the hands of inexperienced operators.

The procedure is as follows: Remove the bark from the base at least. On some stumps it is necessary to dig away a little dirt. The fire should be started low enough so that it will burn in under the stump at the spaces between the roots.

Directions

Gather some fuel wood—any kind that will make good coals, though mixed oak and a little pine likely will be best. Cut this wood like stove wood—say about a foot long, and split fairly fine. Lay and stand the sticks round the stump till you have a layer at least 6 or 8 inches thick. You can pile wood and start the fire entirely round the stump, or only about a quarter of the way round as you prefer. Putting wood all round takes more wood and more time to prepare, but burns the stump out quicker and has more chance of success.

After the wood is in place it must be covered with a little straw, fern or other material of the kind, and then with a thin layer of dirt. The dirt layer should not be more than 3 or 4 inches thick. It must be of clay or very heavy soil. The dirt should be piled against the stump up to about 18 inches high, but no higher.

Start the fire at each quarter of the space round the stump. That is, if the wood runs only a quarter way round, start one fire; if all the way round, start 4 fires. Leave the holes where the fire is started open only for a little while, and then cover them up.

The fire must be kept covered all the time and never be allowed to burn into an open blaze. It is really smouldering and coaling of the wood. When the fire blazes much of the fuel supplied is burned up and the heat is lost instead of forced to eat its way into the stump. The object is to confine the heat. When this is properly done the fire becomes intensely hot round the stump.

As the stump burns through and the fire goes deeper, the dirt cover may break through. Such places must be covered with more dirt. If the fire burns higher up the stump than where the dirt is piled in the first place, put it out up there instead of trying to pile the dirt higher.

As soon as the stump is burned through, the top will settle down and continue to burn. Keep the fire covered over the ends of roots that burn off, so it will eat its way deep into the ground. If it breaks out to the air it will not burn far. While the stumps are burning they must be watched and visited several times a day.

The cost of charpitting in the manner described is high when the actual time of the operator must be accounted for at regular rates of wages.

Idaho Charpitting

Another good method of burning that really is charpitting of a modified form, is to saw the stumps off close to the ground, block up the top part, and to start a fire between the two sawed faces. The faces should be as close together as possible while allowing the fire to be started and to burn. Bank up the outside with dirt, as directed in preceding paragraphs, and keep the fire covered till the stump, roots and all, is consumed. Use stones to hold the two parts of the stump apart. It is best to do the sawing in the winter and raise the top part then, leaving it to dry out several months. The burning is done best in the summer.

Torch Burning

Burning with a torch is simply a matter of digging away the ground from the roots, and applying the intensely hot flame at a point below the plow line. Torch burning is expensive business when time and fuel costs are counted up. The best kind of a torch to use is one with a fan or bellows. The kind of fuel used by the torch is not important, except that some fuels burn better than others. Gasoline perhaps is best.

Plain Burning

A modification of charpitting sometimes is advisable in the case of pasturing the land for several years. The stumps are split and their roots uncovered with small charges of explosives. When they are thoroly dry; wood is piled between and over the split tops of the stumps and the whole thing is set on fire. With a little attention to keeping the burning ends of the roots covered with ashes and dirt toward the last, stumps may be consumed entirely by this method. It is not nearly so much trouble as charpitting, because the fire burns fiercely in the dry, shattered tops, and needs no attention other than the first piling of the fuel till it is time to look after the burning out of roots.

Pulling Out Stumps

Four forms of pulling are worth considering. These are by horses direct, with hand pullers and capstan pullers, and with donkey engines and traction engines.

Four Forms of Pulling

A good heavy team of steady horses will take out most of the stumps which should be pulled whole, and almost any roots left by proper use of explosives where blasting and pulling are used in combination. You will need a couple of good log chains and a regular outfit of singletrees and spreaders. To increase the strength of the direct pull, you can use a frame made of 6 by 6 pine pieces in the shape of the letter A. Make it 6 feet high. Attach a short piece of chain round the tip of the A, to run down to the roots over the top of the stump, or else run the main chain from the horses over the top of this frame before attaching to the stump. Such a haul will upset a stump much easier than a direct hitch.

If you have to pull without the frame, aim to pass the chain over the top of the stump and hitch to a root on the other side, the farther out the better. Another good hitch and haul is the twist. Hitch to a root and drive so that the chain tends to wrap round the stump.

When saplings are to be removed do not cut them first, but hitch the chain to them as far up as you can reach. While the team is hauling on them, a man should cut the roots on the opposite side with an axe.

A few days of stump pulling is enough at one time. Rest the horses and men at some other work. The clearing of land by this method is heavy and tiresome, and can easily become disheartening if kept up too long.

A capstan puller consists of a frame, a drum on bearings, a pole to hitch horses to, and a wire cable fastened to the drum. Some of them have gearing which reduces the speed of the drum and increases its pulling power. These work very slowly.

Capstan Pullers

The pullers have to be anchored to solid stumps near the place where they are set up. The limiting factor in the use of pullers is this anchor or anchors. When you pull, you do not always know whether the stump out at the end of the cable or the one behind the machine will come. To set the machine takes time, and you should be careful to make the anchorage as secure as possible.

If your puller comes without a pole, you can get one in the woods near home. Cut a 6-inch tree—ash, white oak, hickory or the like—and use a 20-foot length. Better attach an old wagon tongue to this where the horses are to be hitched, to keep the pole from hitting the horses when stumps give way suddenly. Some operators also attach a second pole in front of the horses, to lead them in the circle, saving continued driving.

It is better to wind up the cable on an empty drum; the cable wears much less in this way. For that reason use only enough cable to cover the drum—not two layers on it. The length of the cable will govern the area you can clear with one set of the machines. This usually will be about an acre.

Three men can clear an average acre of cut-over land of small stumps in one day. Three men will handle a small outfit. Handling the cable is heavy work, and you want no boys on the job. The hooks for catching the roots that come with the machines usually are poorly designed. You can have a better one made by welding together two old steel plowshares in a manner that your blacksmith will understand if you show him the original hook. For best results a hook should weigh about 50 pounds, though to be so light it must contain only good steel.

Time to Pull

Pullers are not suited for taking out occasional stumps in cultivated fields, but only to clearing cut-over land where stumps stand close together. The machine should be brought on the job only after the necessary blasting has been done. Then the small stumps and whatever roots are left by the blasting can be taken out at the same time. A supply of explosives should be kept on hand for blasting out the anchor stumps after the machine has done all the work it can.

A tripod puller is effective, but cumbersome to handle and expensive to operate. It is not recommended.

A donkey engine for stump pulling should have about the same power as for logging operations, and should be constructed about the same. There should be two drums, one for the pulling cable and the other for the return line, the return drum geared faster than on a logging donkey.

Donkey Engine Outfit

About 350 feet of pulling cable can be used. Inch or inch and a quarter cable usually will be best. The return line would be half or five-eighths inch. With 350 feet of main cable, 10 acres can be cleared at one setting. It speeds up operations to use a cluster cable with three or four hooks. Several small stumps can be pulled at once with this.

A donkey engine outfit requires five or six men to operate it. With it stumps of any size can be pulled. When they are too big to handle directly it is best to break them up with explosives before attempting to burn or otherwise dispose of them. Very large stumps should be loosened and split before they are pulled.

Traction Engine Pulling

Little needs to be said about using a traction engine. You will need heavy chains and heavy hooks. The chain should be nothing less than five-eighths inch. A short piece of inch or larger wire cable is better. Fifty feet or so is enough. The hook should be of steel, with one point, and should weigh 50 to 100 pounds. The entire hitching apparatus should be strong enough to stand jerking on with the weight and power of the engine.

Cost

The cost of operating pulling machines and of clearing land with them varies so much that no figures are safe to depend on. It depends on the kind of soil, the kind of stumps and especially on the skill with which the machines are operated. When everything is at the very best, land can be cleared economically with donkey engines and traction engines in combination with explosives. When conditions are not favorable the cost of these methods is very high.

Tools

For any kind of stump pulling you will need shovels, hoes, axes and bars. The probing rod also is useful for locating roots.

Blasting Out Stumps

The directions for removing stumps with explosives are given in full detail, and in order to do the matter justice they are placed in a separate chapter.

Blasting Out Stumps

A proper charge of explosives placed under a stump will tear the roots loose, lift the whole stump out, and break it into pieces. The whole operation is simple, safe, short and easy. Any sort of stump, of any size, in any soil, any weather, can be blasted out successfully, and the blasting is a practical and efficient method whether there is one stump to be removed from the middle of a cultivated field or a lawn, or thousands of acres of the heaviest logged-off land clearing to be done.

It is folly to attempt to blast out many big stumps, such as this one, without an electric blasting machine. Such a stump should have six to eight charges properly located about it. These numerous charges will contain less total explosive than one charge large enough to remove the stump. The hole they make is much smaller.

The best time of the year to blast out stumps is a matter of compromise between conflicting requirements. On the one hand explosives work most effectively in moist clay and wet sand soils. On the other hand, it is bad from a tillage standpoint to blast heavy ground when wet. (See page 38 for further discussion.)

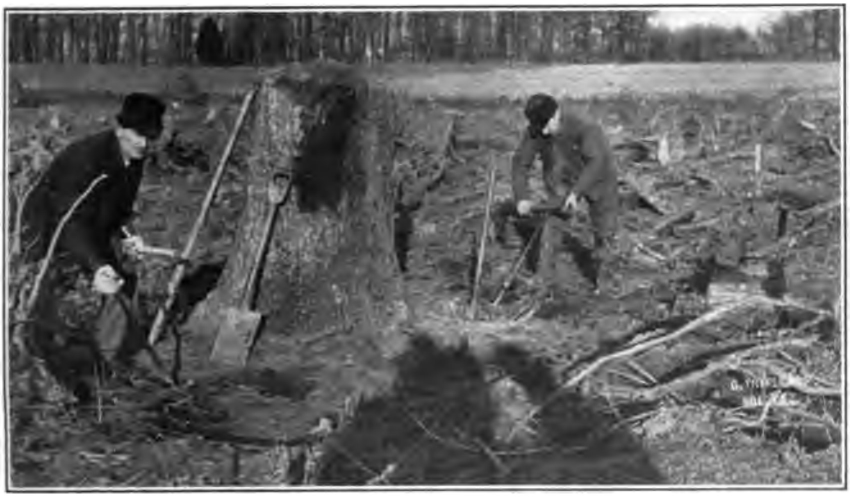
With all the facts before you, the selection of time is a matter for your own judgment. If cost did not need to be considered, summer or fall would

Time of Year be ideal. Blasting out stumps from frozen ground can be done with satisfaction. In fact, the stumps are broken up better then than at any other time, though the work is harder on account of the difficulty of making holes.

Success, and especially economy, in stump blasting, is a matter of common sense and judgment plus some knowledge of the stumps and of explosives. Close attention to apparently small matters insures good work. The things that the blaster must consider are the location for the charges, the proper size of holes, the amount of explosives required, the length of fuse, depth of hole, tamping and the like.

Loading Charges of Explosive

To blast out a stump the explosives must be placed in a hole underneath it. Make the hole first. Then prepare the charge of explosives as directed on pages 34 to 38. Pack the explosives in the hole, tamp and fire.



In blasting out big green stumps, the holes for the three to eight charges should be made as nearly as possible under the main anchor roots. The man on the right is smoothing out a hole, getting it ready for the charge; the one on the left is shoving a stick home with the tamping rod.

Load stumps by no rule, but with regard to their root systems and to the nature of the soil. The aim is to tear the roots out of their anchorage in the ground, or to break them off below tillage depth. To do this you must place

Depth for Charges the charge or charges of explosives as close to their burden as possible—hitch them as short as possible to the load. The load or burden is not the weight of the stump so much as its grip on the ground. You must get good confinement of the gases. If there is a weak wall on one side of an explosion and a fairly solid or firm wall on the other, the weak wall will give way, and very little breakage or movement will be made in the other.

The charge of explosives should be located just deep enough to secure this confinement and to be under the load to be lifted, but not any deeper. If charges are too deep there is great waste of energy in uselessly lifting earth. This is costly. Charges that are placed too shallow will blow off the tops of stumps or split them, leaving roots tight in the ground.

Since clay and other heavy soils hold the gases much better than sand, and wet ground holds them better than dry ground, a much thicker covering of dry sand is required over a charge to confine the gases properly than of wet clay. Charges, therefore, must be placed deeper in sand. Usually the charges should be placed right next to the wood of the roots in clay soil, and in sand with 6 to 30 inches of ground between the charge and the roots (tap rcots excepted—see next page). Large stumps, and old stumps, require shallower placing of charges in proportion to diameter than small stumps and green stumps. Long-rooted stumps require deeper placing than short-rooted ones.

The charges are placed and the wires connected, the stock has been chased away and the helpers warned back—now the blaster is ready to shove the handle of his machine down and to fire the explosive.

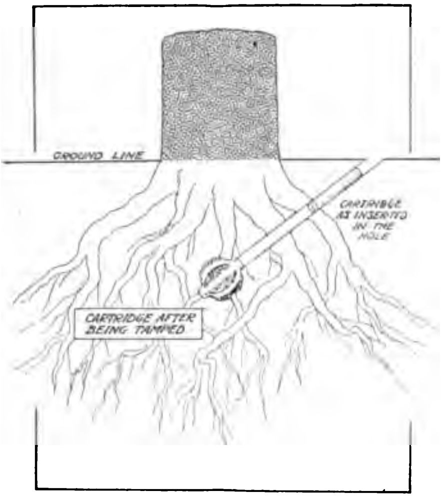
With the foregoing points in mind, it will be seen that the charges should be placed directly under that part of the stump that will give the greatest resistance. This may be the center, but it is by no means always so. If the stumps have grown on a hillside, the roots may be heavier cut sideways than uphill or downhill. Very often a tree on the level has heavier roots on one side than on the other. Usually it is of advantage to blast a big stump with more than one charge, placing one charge under each of the large roots and one under the center of the stump. A charge under a root should be at a point where the weight of the stump will be balanced by the pull of the ground at the other end. This point usually will be a foot or two out from the edge of the body of the stump.

In the foregoing suggestions, no mention has been made of the three main types of root growth—tap-root, semi-tap root and lateral root; but with the principles of blasting in mind, it is easy to see that a properly placed charge under a lateral root stump will be very shallow. If such a stump is to be taken out with several charges instead of only one, all but one of the charges will have to be located well out from the stumps proper, under main roots.

Semi-tap root stumps require deeper placing of charges than lateral root stumps. When such stumps are taken out with more than one charge, the points for the explosive are closer in, under the main roots where they dip a couple of feet below the surface.

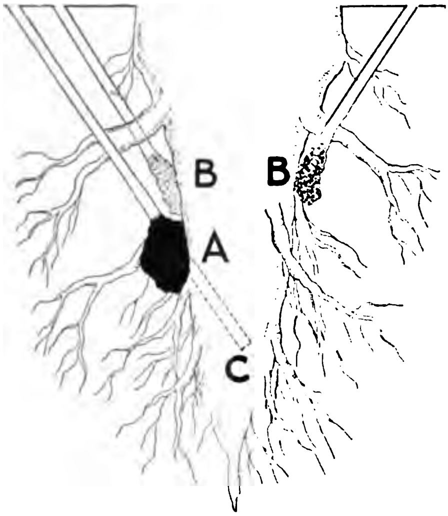
The underground nature of each stump should be determined before placing charge or even making holes. You can do this partly by observing the roots that rise above the surface, but mostly by probing down among the roots with the quarter-inch steel needle known as a probing rod. Every blaster should have one of these rods and should make use of it at each stump.

There are two ways of blasting out true tap-root stumps. One is to bore a hole in the wood of the tap-root itself, and the other is to place the charges right alongside the root and against it, like mudcap charges are placed in stone blasting. In placing the charge in the wood, make a hole in the ground down to a point a couple of feet below the surface of the ground. Then bore a hole in the wood with a wood auger. This hole should go two-thirds or three-fourths of the way through the root. Fill the hole in the wood with explosives, fire, and the resulting blast will cut off the root.


GROUND LINE
CARTRIDGE AS INSERTED IN THE HOLE
CARTRIDGE AFTER BEING TAMPED

How cartridges of powder swell and fill the hole when they are split and pressed with tamping stick.

In placing the charge of explosives against the wood, get it at least 4 feet deep. If you can command an electric blasting machine for firing, divide the charge in two and place the two parts on opposite sides. These charges may be placed only 3½ feet deep, though you should not hesitate to place the charges at a greater depth when blasting large tap-root stumps, particularly if the ground is of a light nature.

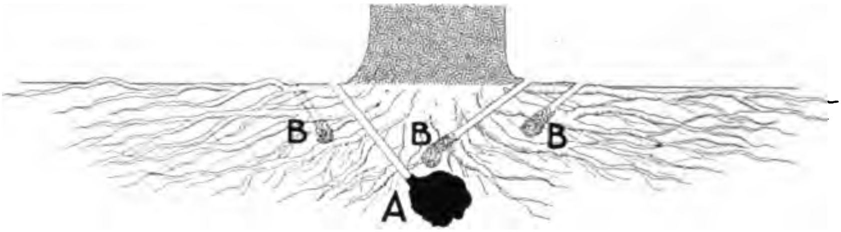


How to place charges for blasting out tap-rooted stump. Three methods are shown. "A" shows how to do it with one charge, using cap and fuse and not boring into the wood. "B" shows how to place two charges when electric blasting machine is available. "C" shows by dotted lines position of auger hole in wood where one charge could be placed to cut off the root and throw out the stump. Any one of the three methods will do the work.

Making Holes

In all sorts of stump blasting the holes for the charges can be dug with narrow-bladed shovels, spades or crowbars, or bored with dirt augers. (See page 32.) In stony land augers cannot be used, or can be used only for parts of the holes. All things considered, it is hard to beat the bar and sledge combination for making holes for charges of no more than two or three sticks, or for starting holes for larger charges.

The bored hole is better than the dug one because it can be tamped tighter. After much dirt once is taken out, it will not be tamped back in again as solid as it was before. Holes for inch-and-a-quarter sticks of explosives should be made with inch-and-a-half augers or bars. In blasting exceptionally large stumps, use 2-inch or 3-inch augers. The holes usually can be started between roots and in depressions, but do not sacrifice good placing of charges for ease in making holes.

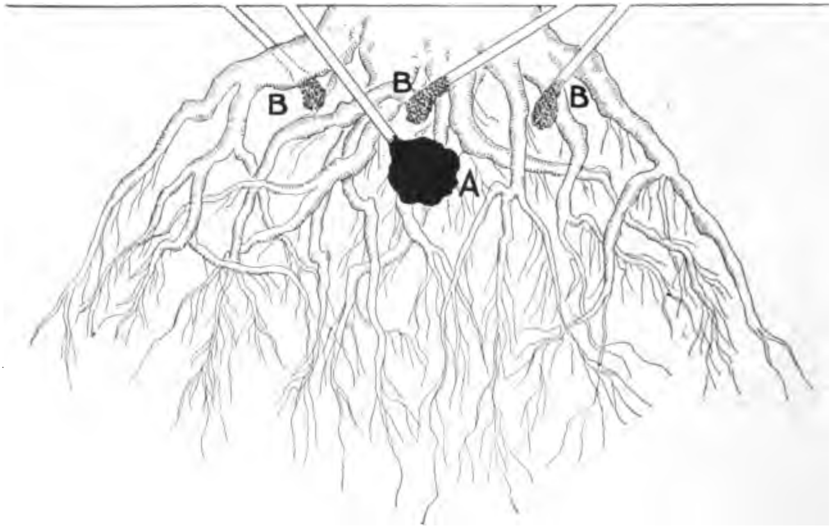


How to place charges under lateral rooted stump. "A" shows how to place charge when the cap and fuse are used and one charge is relied upon to remove the stump. "B" shows how to place three small charges under main roots when stump is to be removed with several charges fired by electric blasting machine. Use either method "A" or "B"—never both.

In water-saturated ground of a heavy nature, in case you have difficulty in getting the charge properly centered or placed (when no electric blasting machine is available for firing), you can make use of what is known as propagated detonation. Divide the big charge into several small ones in different holes bored from two, three or four sides of the stump, but all ending close together down under at the right point. If these charges are tamped solid and they are not more than a foot apart they all will explode at once when one of them is fired with a cap and fuse in the usual way.

In making holes for blasting out tap-root stumps, start the bar or auger straight down along the root from the surface. When you have reached the required depth, wriggle the bar sideways to make the hole wide at the bottom.

Wherever the number of stumps runs into many thousands, it will pay to get a machine to bore the holes. Such a machine will bore all the holes needed

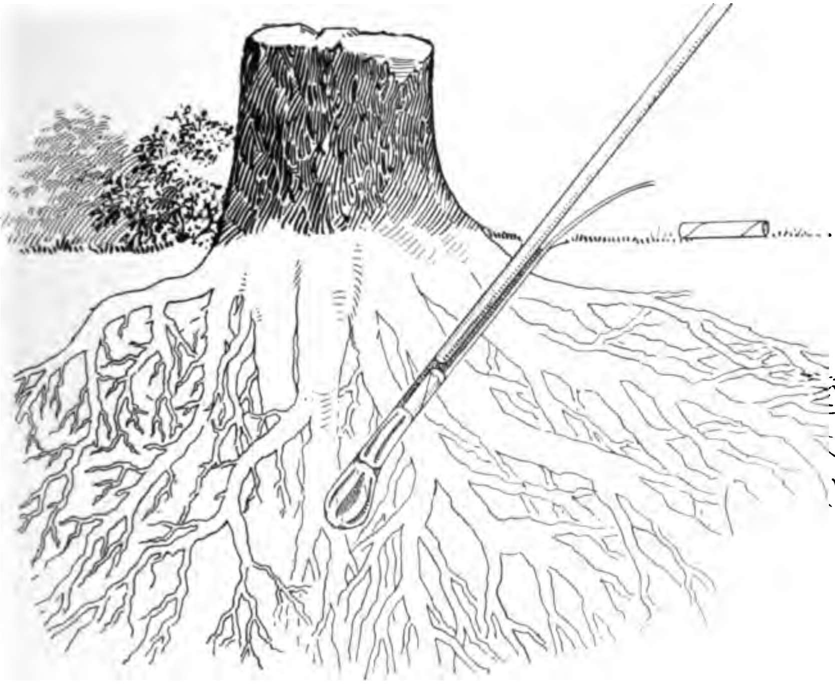


How to place the charges under semi-tap-rooted stumps. "A" shows proper position where one charge and cap and fuse are used. "B" shows proper positions of several small charges when electric blasting machine is used. Use either one or the other method illustrated—never both.

under the stumps at the rate of 500 or 600 a day, and at very much lower cost than the same work can be done by hand. The machine bores almost as fast in wood as in earth, and is particularly serviceable when roots have to be penetrated in order to get the charges to the right spots.

Power Boring

Machines can be bought complete in small sizes suited to land-clearing purposes, or can be bought in parts and assembled on home-made frames. Electric machines are most convenient. Steam and compressed air machines are next best. Flexible shaft machines and direct-geared machines are least satisfactory. The flexible shafts break. The steam outfits freeze up and are troubled with burst pipes. All the outfits except steam ones can be run by gasoline engines.



To show sticks of explosives expanded, as permitted by splitting of stick wrappings, in big hole.

An electric boring outfit consists of a small gasoline engine—say about 5 horse power—on a wagon belted or geared to a 3 kilowatt dynamo, and that equipped with two drill heads and 200 feet of electric cable. A supply of 1½-inch augers completes the outfit. Such an outfit costs about $500. You can use any gas engine. The dynamo will cost somewhat less than $250, and the drills about $80 each.

It takes five men to run this outfit—two men on each drill and one man to drive and to handle the cables. This man should lift the cables carefully over stumps and prevent them from kinking and getting caught. The steam and compressed air and the direct drive machines will not be described, because improvements continually are coming out. Watch the farm papers for advertisements, or write to any maker of explosives for names of manufacturers of these machines, if you are interested in them.

Study the methods of handling explosives as outlined on pages 34 to 40 and 58 to 61, to which every reader is referred at this point, before trying to load charges. A few special hints will be given here.

Charges of explosives usually should be as near as may be in a round bulk—not strung out for 2 or 3 feet in a long hole. To get them so the hole must be enlarged at the bottom by scraping or springing. Slit the paper wrappings of the sticks and press the sticks in the hole with the tamping stick till they swell to fit the hole tight and shorten to 2 to 4 inches in length. (See pages 24 to 26.) But do not do this if the hole is very wet.

Slit Stick Wrappings

When you have many stumps to blast out, it often is a good practice to make holes in the forenoon and then to load and shoot after dinner. Load and fire all the holes you have prepared when you go to the field, after which you can proceed to make more holes. *Always fire the charges soon after they are loaded.* To do this prevents missing charges, and avoids chance explosions due to meddling, and the like. If the holes are wet, firing immediately is required to avoid weakening of the explosive by water.

If you prepare your charges in the field, you can cut a supply of pieces of fuse before you go out. Make the pieces of varying lengths and crimp caps on them to prevent the powder shaking out of the ends. Take the roll along with you to provide for holes requiring longer fuse. Don't attempt to use pieces of fuse less than 15 inches long. They are dangerous.

Use plenty of water when tamping the holes, and tamp well. See that the ground is packed solid, not only where you made the hole, but all around the stump. Often there are holes dug by skunks, groundhogs, gophers, squirrels, rats or mice under stumps. Keep the charge of explosives away from these cavities—better fill them up.

Some such appearance is necessary in stump blasting, but the less of it there is the better. The ideal blast is just strong enough, and is so located, that it rolls the roots free of their beds and splits them apart, but does not throw them an unnecessary foot. Loud reports and much dirt high in the air show careless loading and useless expense.

In lighting many fuses a gasoline or oil torch is useful. But there isn't anything much better than to stick the burning end of a freshly scratched match right against the powder in the end of the fuse. (See page 58.) Remember that the outside cover of the fuse does not burn, but the spark runs down the center as a drop of water might run down a tube. Do not leave the fuse till it spits sparks regularly.

None of your charges are likely to misfire if you load carefully, and if you have taken proper care of your explosive materials before loading. But if misfires do occur with fuse, do not investigate them for several hours, at least. (See page 63 for discussion of misfires.)

Misfires

Of course, in electric firing you can

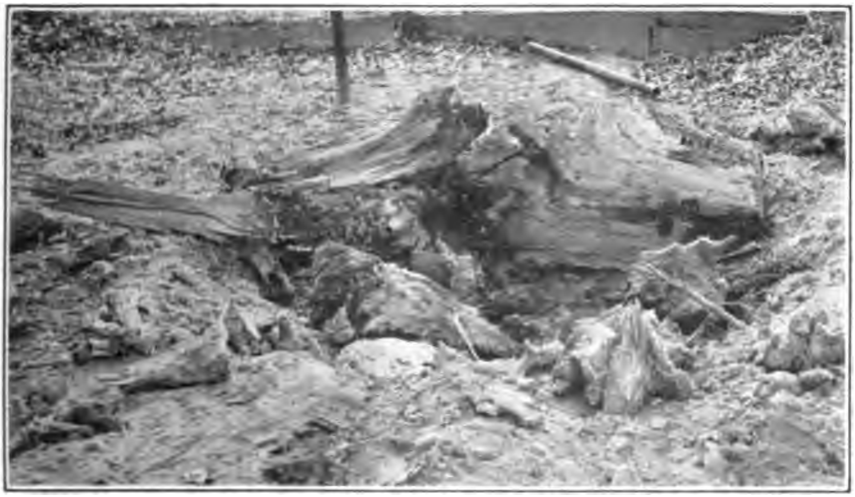
investigate a misfire immediately after the wires have been disconnected at the blasting machine.

Amount of Explosives Required to Blast Out Stumps

A proper charge of explosives for a stump blast has a dead, muffled report. It lifts out and splits the stump. Loud report and the throwing of the pieces far shows that too much explosives have been used. When stumps merely are split and tight roots are left, not enough explosives have been used (or it may be placed too shallow). If the explosion is muffled and does not throw pieces far, but digs too big a hole, the charge is too heavy and too deeply placed.

It is impossible to lay down exact rules for the amounts of explosives to use. This bulletin will include figures of amounts that have been used to blast out some stumps, but these figures must be regarded as correct only under identical conditions of soil, kind and age and size of stump, amount of water in soil, kind and grade of explosives, and amount of confinement in the hole. Experience must be the teacher in this matter.

A green stump requires a great deal more explosive than one that has stood a few years. More explosives are required in stony land than in smooth land to blast out stumps. The harder and heavier the soil is, the less explosives are required, and the looser and lighter it is the more explosives are required. Dry soil requires more explosives than moist soil.



As these roots lie, they show the result of an almost ideal blast. There is little hole in the ground; the stump is well broken up; the roots are cleaned of dirt; and no roots have been thrown very far.

When you want to blast a stump entirely out, it is better to load too heavily than too lightly, for roots left tight in the ground after the top of a stump is blasted off are hard to get out. If you are not familiar with stump blasting, start with the small stumps and load them as you think they should be after considering the various points explained in foregoing pages, and in view of the following figures.

Ordinarily it takes one pound of explosives for each foot in diameter of stump, when the stump is such as a white pine in clay soil cut 10 years or longer. Green stumps of any kind require more than this—usually about half again as much; sometimes twice as much. A rule for the enormous stumps of the Pacific Coast is to square the diameter of the stump, measured in feet, and use this figure as the number of 1¼ by 8 inch sticks of explosives required. This rule usually over-estimates the amount required for stumps larger than 3 feet in diameter.

Examples of the incomplete job resulting from trying to blast out very big stumps having wide-spreading roots, with one charge to each one. Unless the charge is excessively heavy, which means that it is expensive in explosives and in loading, it can not be placed deep enough to remove the whole stump. Even if it is deep enough and heavy enough to be successful it is objectionable on account of the big crater made. Each big stump should have several charges.

Amount of Explosives Used to Blast Stumps

The following table is taken from records of blasting in Minnesota, Pennsylvania, Oregon, Kentucky, Michigan and Florida. The stumps were blown out effectively and successfully, and the figures should serve as a reliable guide.

Diameter Stump Inches	Kind Stump	Kind Soil	Sticks 1¼ inch Dynamite or Powder
10	Pine, dead	Clay	1
12	Pine, dead	Sand	1½
12	Pine, dead	Loam	1
12	Pine, dead	Clay	1
14	Pine, dead	Clay	2
15	Pine, green	Loam	4
16	Pine, dead	Clay	1½
18	Pine, dead	Sand	3
18	Pine, dead	Loam	2
18	Pine, dead	Clay	1½
20	Pine, dead	Sand	7
20	Pine, dead	Clay	4
24	Pine, dead	Loam	5
24	Pine, green	Sand	10
24	Pine, dead	Sand	5½
24	Pine, dead	Loam	4½
24	Pine, dead	Clay	4
36	Pine, dead	Sand	10
36	Pine, dead	Loam	8½
36	Pine, dead	Clay	7½
40	Pine, dead	Clay	7
48	Pine, dead	Sand	13
48	Pine, dead	Loam	10

Diameter Stump Inches	Kind Stump	Kind Soil	Sticks 1¼ inch Dynamite or Powder	
48	Pine, dead	Clay	9	
60	Pine, dead	Clay	15	
8	Oak, dead	Sand	1½	
12	Oak, dead	Sand	2	
12	Oak, dead	Loam	1½	
15	Oak, dead	Loam	1½	
16	Oak, dead	Clay	1½	
16	Oak, green	Clay	3	
18	Oak, dead	Loam	3	
20	Oak, dead	Loam	3½	
24	Oak, dead	Clay	3	
26	Oak, dead	Clay	2	
27	Oak, dead	Sand	5	
27	Oak, dead	Loam	4½	
30	Oak, dead	Clay	4½	
30	Oak, dead	Sand	6	
34	Oak, dead	Clay	4½	
38	Oak, dead	Clay	5½	
30	Fir, dead	Loam	10	
36	Fir, dead	Clay	12	
40	Fir, green	Loam	20	
48	Fir, dead	Loam	26	
72	Fir, dead	Clay	36	
60	Spruce, green	Sand	32	
15	Hemlock, dead	Sand	2	
10	Walnut, dead	Loam	1	
15	Gum, green	Clay	3½	
24	Gum, dead	Sand	4	
16	Black gum, green	Sand	5½	
16	Sugar maple, green	Sand	5½	
20	Snag, dead	Sand	4½	
6	Tap-root pine	Sand	½	Charge in wood
8	Tap-root pine	Sand	¾	
10	Tap-root pine	Sand	1	
12	Tap-root pine	Sand	1½	
15	Tap-root pine	Sand	2	
18	Tap-root pine	Sand	2½	
6	Tap-root pine	Sand	1	Charge against wood
8	Tap-root pine	Sand	1½	
12	Tap-root pine	Sand	3	
15	Tap-root pine	Sand	4	
18	Tap-root pine	Sand	5	

Proper blasts throw out little dirt. They pull the roots out of the ground, and permit most of what little dirt they do lift to fall back in the hole. In consequence good blasting leaves small holes.

An excellent plan for any blaster is to carry a notebook and a yardstick and keep track of the blasts he makes. Make note of the size, kind, age of stump, kind of soil, amount of water, kind and amount of explosives used, and the result of the blast, in each case.

The figures here given will serve as a guide for the first shots. As the work proceeds, base your loading on your own experience.

Here two charges, fired together electrically, were correctly proportioned and placed except that one was located too shallow and too far in toward the center. It should have been out under this remaining root, shown in the picture, which then would not have required pulling with horses or another blast.

Kind of Explosives to Use

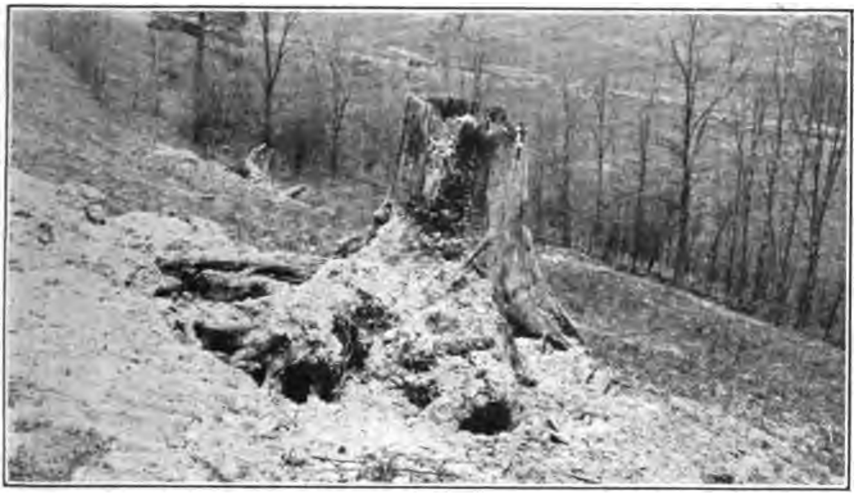
The kinds and grades of explosives best to use for blasting out stumps are few, and vary with the nature of the soil. In a heavy soil an explosive which cracks, lifts and heaves is more desirable than one which shatters. In other words, a slow-acting explosive is the one to use. This means dynamite or powder of 20% strength or less; and further, in dry work or where the charges can be fired quickly after loading, it means ammonia explosives. If the charges must be exposed for some time to water, nitroglycerin powder or dynamite had better be used.

The single charge under this stump was placed too deep and too much to one side. It exhausted most of its energy in the ground far below the roots, and then what was left escaped between the roots, blowing the dirt away but not having enough power to carry the roots with it.

In dry, light soils, such as dry sand, it is necessary to use an explosive that exerts its full force before the gases can give way, as in mudcapping rock. For that reason 50% ammonia or nitroglycerin powder or dynamite is the explosive to use in dry sand and similar soils, or 60% will do. Intermediate grades of soil usually can be depended on to hold the gases enough to permit the use of the slower 20% explosives.

The above does not mean that

these grades of explosives are demanded for removing stumps. The fact is that stumps can be blasted out with almost any explosives manufactured; but the work can be done more economically and cheaply if the grades recommended above are used.



Four charges fired together tore this stump loose from its moorings and moved it six feet down the hill, but did not break it up. Another charge should have been located close under the center. It can be broken up easily now, however, by loading one stick charge down in the center of the hollow top. THIS STUMP IS A WHITE PINE, CUT 75 YEARS AGO.

The 20% explosives, especially the ammonia, leave the ground in better condition. A violent and quick-acting explosive tears out large holes in heavy ground, and packs the earth about the edges.

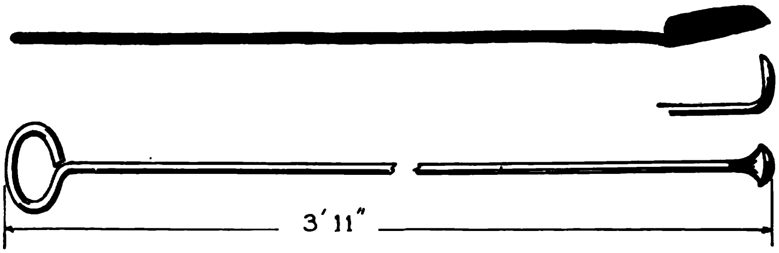
Time Required for and Cost of Blasting Stumps

A day's work for one man is 30 to 60 average stumps blasted out. If three men can work as a crew, two making holes and one loading and firing, the number of stumps per man will be much increased.

The cost of blasting stumps is a variable quantity. Those which blast out the cheapest are well-rotted oak or walnut, in moist clay soil. Probably the stumps which cost most to blast are green white pine or oak in dry sand. The skill and good judgment of the blaster also has much to do with the cost.

Tools

The tools you will need for blasting stumps are all common ones. The pictures show better what they are like than words can tell. You can use grubbing hoes, axes, crowbars for driving and for hand use, soil augers, long-shanked wood augers, wood tamping sticks, cap crimpers, water buckets, pocket



This stump came out as a result of a charge that was placed too deep and a little to one side of the proper position, and is not broken up for handling. It can be broken very easily as it lays, by locating a one stick mudcap charge between the two large roots seen in the picture. Had the original charge been a foot nearer the surface, the stump would have been broken in several pieces and all thrown out.

knives, steel probing rods, adzes, long-handled shovels, spade shovels, spoon shovels, scrapers, spoon bars, sledges and possibly other tools.

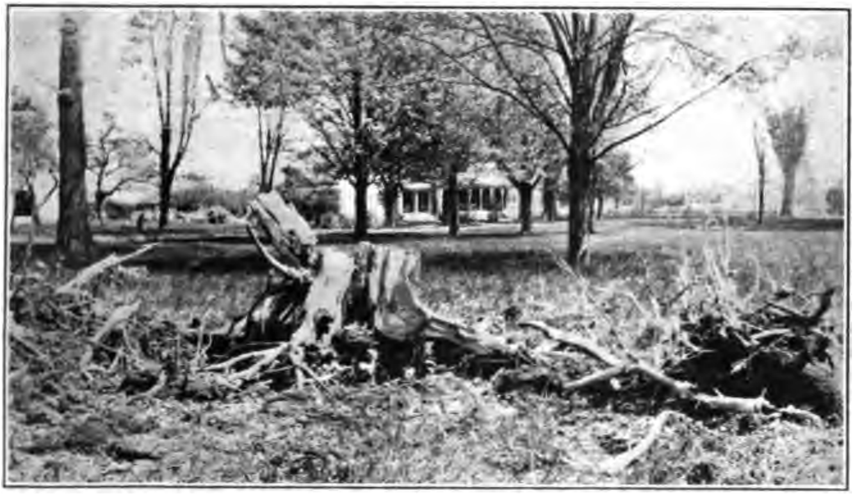
An old wood auger does not make a good soil auger, though it can be used in a pinch. For boring in ground an auger should have a leading point 2 or 3 inches long. Both wood and soil augers should have cutting bits that can be filed sharp a good many times without destroying them. Most blasting tools are supplied by all makers of explosives, and by hardware dealers. Some of them can be made at home, by your blacksmith.

The spoon shovel and spoon bars are for tunneling and enlarging bore holes. Make them by turning up and trimming the edges of long-handled shovels. The probing rod is a piece of quarter-inch steel 6 feet long, with one end sharpened to a point. It had better have a handle turned over, or made into a ring. No long description of any of these tools will be given here, because farmers are familiar with them.

This bulletin recommends electric firing for stump blasting strongly whenever there is enough blasting to be done to justify the purchase of a blasting

A very old white pine stump blown out with three charges fired together electrically. The stump is well torn loose and cleaned, but another charge should have been placed at a point close to the wood under the center, to split the stump for easy handling.

machine. (See page 58.) One to fire up to 10 charges can be obtained at a moderate cost. If skillfully handled its use will save its cost for each 500 pounds of explosive fired. Electric firing makes possible work in stump blasting that is superior to the work produced by any fuse firing when conditions are difficult. The several small explosions help one another.

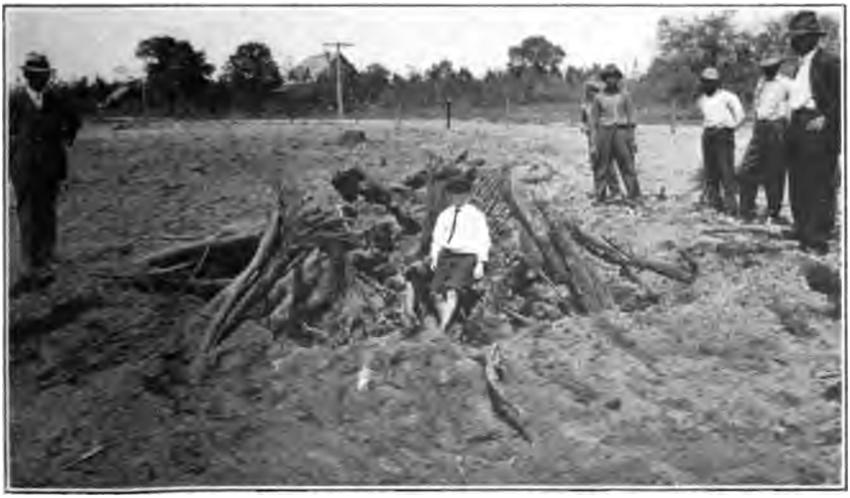


The blaster located his charges under this stump too far toward one side. The result is that the roots of the other side are left sticking in the ground and require another blast.

General Hints

To blast out standing trees, use about twenty per cent. more explosives than you would for the stumps. It is better to blast big trees with several charges, firing them electrically.

When big green stumps are blasted out with one charge placed under the



The result of an attempt to blast out a very large green stump with one charge. The explosives were located deep under the center, but they could not reach out far enough to tear loose the many firmly anchored roots. They blew off the top, instead. Such stumps should be blasted with three or more charges all fired together electrically.

center, some of the roots often break off high up, so that they interfere with plows. They are better blasted with several charges placed round the edges. If you are using a stump puller, split and loosen all the big stumps with explosives before pulling them.

It is more expensive to remove severely burned stumps than those with the tops intact. In blasting decayed stumps and those with no tops, fill the center cavity with ground and tamp it tight. Then place the charges in the usual way.

In blasting old rotten stumps that have sound roots, you often find the center underneath has rotted out, or become so that it is only a mass of punk. This material will not hold the gases of the explosives. To blast such stumps, better use an electric blasting machine, and several charges, or if fuse must be used, place the charges under the roots, or deep under the center, filling the hollow center with wet clay or loam.

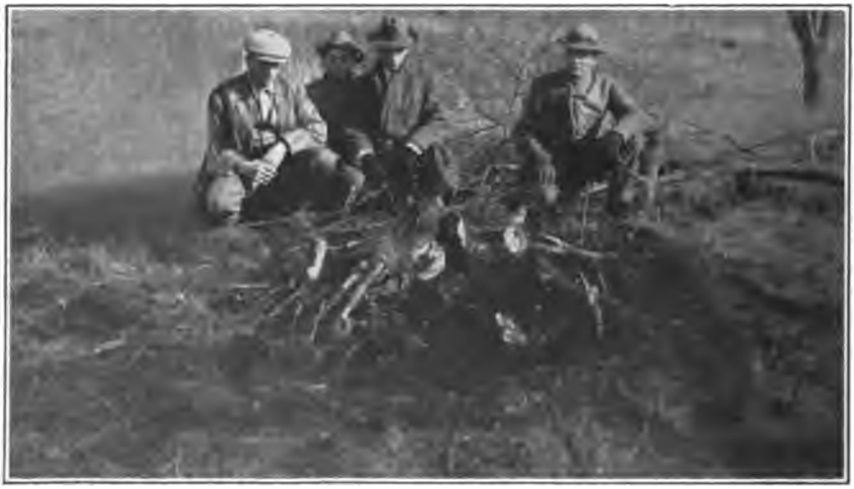
Old logs and snags frequently are too big to haul or handle and to burn on clearings. Do not waste time cutting them in two, but smash them up with charges of about half a stick of explosives placed in an auger hole. If no auger is handy, put a heavier charge in a notch chopped in the log and cover with 6 inches of mud.

Fat pine tap-root stumps often may be shattered by charges of explosives placed in the top-roots, and the stumps left to dry. After a few weeks these stumps will burn like oil pots.

Many farmers can clear their land with very little loss of time from regular work by going about it in a systematic campaign. In an hour or two each evening a good many stumps can be blasted out and the work will be a pleasure. Only one man is needed. By making sure that the charges are rightly placed and proportioned to the stump, the roots all will be broken up so one man can handle them.

Headache Prevention

Avoid working in the fumes and smoke of blasts, which will cause headache. Also keep the explosives from touching the skin of your hands, by wearing gloves.



When the charge is placed too shallow in the blasting of a stump that is newly cut or that has not rotted much, the top is ripped off, leaving many tight roots sticking high enough to catch a plow.

In removing saplings of sassafras and persimmon and stumps with long, tough roots that may sprout if permitted to break off in the ground, it often is of advantage to explode half stick charges a couple of feet under the trunks. This will not take out the trees, but will loosen the ground so that when they are pulled over in the usual way the roots all will come away.

Be careful not to miss charges that are placed, when you are lighting fuse or connecting wires. Get them all as you pass the stumps they are under. Unfired charges are liable to weakening and damage, and are sources of danger.

This is what the stump field should look like after the roots have been blown out. If the land is to be farmed, the next plowing should see every root removed.

Stump Disposal

Stumps make good fireplace wood and kindling wood. You likely can sell fireplace wood in nearby towns by doing a little advertising or inquiring of people you know. Pine stumps have won a place in the hearts of all American farmers as kindling wood. On nearly every farm and at nearly every home it pays to keep a large supply of pine roots for kindling. Don't destroy stumps when your wood-house is empty.

At many points roots can be sold as fuel for engines. In many parts of the South stumps can be sold for turpentine extraction. Everyone should make an effort to sell or to use his stumps rather than to destroy them. They represent real fuel value, and a little effort usually will get it out. The home kindling pile can be made big enough to last for years. The roots are ready-cut kindling of the best grade. As fireplace wood they are superior to top growth, because of mineral elements in the sap. They make as good fuel for lime kilns as any other wood. The price for home use near large cities often is upward of $8 to $12 a cord. For turpentine extraction the roots are worth at least $3.50 a cord. Farmers themselves can afford to pay at least $1.50 a cord, with the cost of hauling added, rather than to burn the stumps.

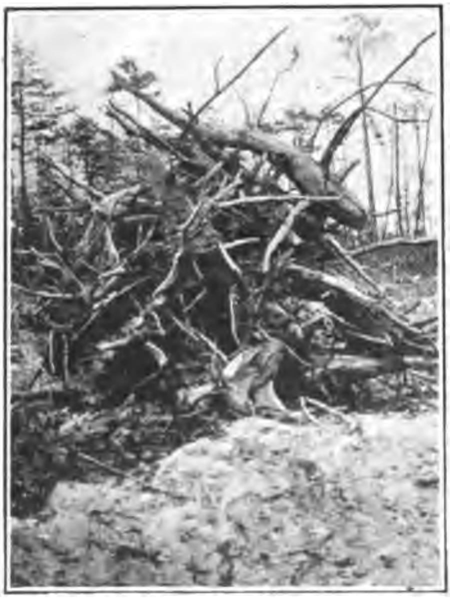
But when stumps cannot be sold or used they must be burned on the ground. Where they have been pulled out, without breaking up with explosives, and are large, the pulling engine or horses must be used to pile them, with the help of a derrick or gin-pole. An engine and a winch, using a cable, is a very good outfit for this purpose. A derrick may be a tripod with legs up to 40 to 45 feet long, or it may be a swinging boom derrick, with mast up to

Wood is a very expensive commodity in many parts of this country to-day. It never will get cheaper. Utilization of all parts of the trees that are cut down in land clearing is the thing to do whenever it is possible.

30 feet high and boom 25 feet long. Let the mast lean a little toward the pile of stumps, so the boom will swing round itself with its load. Another good machine is the Conrath portable piler, much used in Wisconsin. It requires 10 pieces of timber or poles, of which the largest, the two skids and the boom, are 20 to 22 feet long. A gin-pole may be any height that is convenient. An old dead tree makes a good one. Let it burn with the stumps piled about it. With 150 feet of half-inch cable and a pair of double blocks the piling can be done with horses.

A better way to handle stumps than with a derrick is to use small charges of explosives to break them up after they are pulled. When stumps are well blasted the problem of disposal is simple.

Start numerous small fires and haul and pile the roots on as they burn down. The fires can be kept going till all the roots are burned up, by putting on new roots and by shoving in butts. Have a wagon or sled and keep hauling and unloading all the time. Drive about the clearing on regular routes, each time making larger circles and throwing off a few roots as you pass by each fire. One man can clean up more acreage in this way in an equal time than several men working to pile the stumps in high piles with a derrick, except in cases where



The ideal size and kind of pile for burning stumps and roots. These piles can be built by hand, in unloading the stumps from a low wagon or sled. The fires can be started and more roots fed to keep them going.

the stumps are large and unbroken, or are left in very large pieces. What saves expense is piling by hand.

When you clear land by blasting, postpone all burning of brush, logs, etc., till after the stumps are blasted. Then have a grand burning of everything at once. But do not burn the surface—don't let the fire run over the ground. Keep it strictly to the boundaries of the piles. There is a whole lot of fertilizer in the layer of leaves, moss, twigs and other vegetable matter that every piece of cut-over or logged-off land has on the surface. It is foolishness to destroy this. Plow it down. It is worth a good many dollars on every acre.

When you burn a clearing, first get in touch with the fire warden of the district if there is any forested land at all near your place. Use every precaution to prevent the fire from getting out of your clearing and beyond your control.

Blasting Benefits Soil

You will hear—once in a long while—some man say that blasting out stumps hurts the soil. When you do, tell him he is mistaken. Proper blasting is beneficial to the soil. It is so beneficial that on thousands of farms subsoil blasting is regarded as a standard practice. In many orchard sections no one thinks of planting fruit or shade trees without first preparing the ground for them by blasting. There is a bulletin published on that subject which you should have if you are interested.

It is proper to add here, however, that when the ground is wet a blast does not produce the same effect in it as when it is dry. Subsoil blasting must be done when the ground is dry enough to crumble. Blasting a heavy soil that is in a plastic condition will make it more compact instead of loosening it. It is possible to do damage to a spot in a cultivated field by making a hole there—by digging out a stump, pulling a stump or blasting out a stump—and failing to fill it up level with the surrounding surface.

A good method of piling certain kinds of green roots. Piles even as large as this will prove to be more expensive than smaller piles in nearly every instance, and this method is justified only when stumps that do not burn well, such as green cypress, pine and fir, have to be burned quickly.

This bulletin states, correctly, that explosives take stumps out most efficiently when the ground is moist. While this is true, if you want to secure subsoiling benefit to the land at the same time you blast out stumps, you must do the work when the ground is at least reasonably dry. By blasting the stumps when the soil is not wet you sacrifice some of the efficiency of the explosives in the stump removing, and gain in fertility.

Clearing Sprouts

Don't allow the second growth to start at all. Pasture the land with what stock you have. To get goats especially for the purpose is practicable on large tracts, but the small tract had better be pastured by the cattle or hogs or sheep that the farm already has. Goat clearing is advisable only where time is plenty and money for development is scarce. Cut brush to the ground when it is in full leaf. Do the grubbing at intervals through the summer, as time permits. Remember that the grubbing must be deep to kill the roots—a foot down at least.

In this operation four men and five horses are used to pile the stumps. The gin-pole is a modification of the swinging boom derrick. The operation is rather expensive owing to its comparative inefficiency compared to hand-handling of the stumps when they are well broken.

Finishing Up New Lands

After the stumps and sprouts are off the land, there still is some work to do before it is ready for crops. New land is fertile, but it usually needs lime. The unevenness and stump holes should be filled after the plowing is done. A small horse scraper is a valuable implement for this, but anything made like a King split-log road drag will do the work. Make a complete job of the leveling. Scrape the bumps into the hollows, and make the surface as even as possible, so that no water will stand in pools. This leveling should be done carefully in old cultivated fields as well as in new ground.

Crops for New Ground

To take full advantage of the big supply of plant food available in the soil of newly cleared land, you must plant crops that will bring in money. This may be a grain such as corn, but is more likely to be hay, cotton or fruit.

Strawberries are pre-eminently a new land crop. They never do as well on old land. If you have marketing facilities for them, put your new ground in strawberries for two or three years.

Potatoes are another paying crop on new land. Corn bears fairly well, but not much better than on old land. Other quick-bearing fruits, such as gooseberries, currants, raspberries and dewberries, do very well. Vegetables like tomatoes, sweet corn, watermelons, beets and squash, succeed very well. Oats is a very bad crop to plant because of the weeds it invariably helps to spring up.

The hay crops are excellent, and in some of them there is a great deal of profit. Alfalfa is the best of them all. If you are planning to plant alfalfa, wait two years after clearing and plowing, meanwhile giving the land a heavy application of lime and cultivating it in some of the other crops named. All the clovers are good. Some people like to sow clover and timothy mixed.

On high land sow red clover and timothy; on low land alsike, timothy and red top grass. Soy beans, Canada field peas, field beans, cowpeas, mammoth clover and sweet clover, cotton and tobacco, all will yield enormous crops on new ground.

A type of "gin-pole" used to pile stumps for burning. Often piling by hand in small piles is much cheaper.

If you have cleared in the summer, harrow and disc at once, and sow rye, to be plowed down the next spring if you are going to cultivate the land, or to be mowed if you sow grass seed. The clover should be sowed on the surface of the ground just as the snow leaves in the spring. If you do not get a good stand from the first seeding, do not be satisfied with the poor one, but tear it up and seed over again. You cannot afford to let new ground loaf. There is money in making it work.

Preparing Charges of Explosives for Firing

What a Charge is

A charge of explosives for the purposes of these directions is considered to be all the explosives needed for a single hole with cap and fuse or electric blasting cap properly inserted in the stick of dynamite or powder (see pages 44 to 45) and tamped in the hole, ready to fire. The preparation of charges is practically the same for all sorts of farm blasting. The slight variations advisable to suit different kinds of work are not enough to call for separate treatment, since the principles are all the same.

All who use and buy explosives should read the next chapter, beginning on page 51, on the nature and actions of explosives. It is only the man who understands all the facts mentioned there who will be able to load and blast with greatest ease, speed and results.

Scope of This Chapter

It is important for everyone who blasts to understand why he does things, as well as how to do them. For that reason the following discussion of the preparation of charges is made full and complete, with due attention to all the important factors involved. Details of any particular part of the operation can be found quickly by referring to the heading desired, as given in the index.

Readers who may not desire a full discussion are referred to the following brief outline of the process.

Be careful that explosives, cap and fuse are in perfect condition. Cut a length of fuse sufficient for the hole to be loaded, making the cut clean, without dragging ends, at a slight slant of, say, 30 to 45 degrees from right angle.

Pick a cap from the little tin cap box, carefully, with your fingers, and slide it gently on the end of the fuse. With a proper cap crimper fasten the cap securely to the fuse, making the crimp close to the open end of cap. Avoid twisting or punching the end of fuse against the bottom of cap as well as drawing it away from the bottom. For wet work waterproof the joint of cap and fuse with tallow, soap or other material. Do not use thin grease or oil.

Next punch a hole at a long slant in the side of the stick to be primed. Better use a wooden punch for the purpose. The handle of the cap crimper may be used.

Insert the cap in the hole made as described, tie the fuse in place, and, for wet work, waterproof all openings in the stick. You then are ready to load.

Provide space enough in the hole at the proper point to hold the required amount of explosives in a bulk that is not too long. Be sure before you start to press in the sticks to the bottom of the hole (see page 26) that there is enough clearance to permit their easy and certain entrance. Tamp fully and firmly up to the top of the hole.

The charge is now ready to fire, which may be done by pressing the burning or flaring head of a freshly scratched match against the powder in the split end of the fuse.

Carrying Explosives and Supplies

Protection of Explosives

The place to keep the explosives is in the magazine or storage place, and not with you in the field. Carry with you in warm weather only enough for the job or the day, or in cold weather only as much as can be kept warm and in condition for firing until you are through loading. Keep explosives separate from caps.

A good way to carry the caps, fuse and small tools is in a basket. Put a piece of blanket in the bottom, to keep

out dampness when the basket is on the ground. Some blasters use an explosives box for the purpose, putting a wood handle or double wire bale on it. The tight wood box probably is a little better than the basket because it affords somewhat more complete protection to the contents.

Whatever the method of carrying the explosives, it should be well protected. This consists in keeping the hot sun off it, keeping rain and fog off it, keeping it away from dampness of the ground, and keeping it safe from meddlesome people and animals.

Many blasters prepare charges before going to the field, but it is better practice to carry along the tools and materials, and to put them together or make the primers on the spot after all the holes are made in the ground or rock, and when everything is ready for the firing except to put the explosive in place.

These remarks are given as reminders. Full discussion of proper handling and storing of explosives can be found on pages 66 to 68 respectively.

Tools and Materials Required

The first step in preparation of charges is to assemble the following: as many sticks of explosive (or parts of stick, if charges are to be less than full sticks) as there are holes to be primed; an equal number of caps; a sufficient quantity of fuse; some string; a wood punch with an end the size of a cap for about 3 inches; a pair of cap crimpers; a pocket knife. If the holes are very damp or full of water you also will need some tallow or other waterproofing material. In certain cases a sharp hatchet or axe and a block of wood will be worth having. The purpose and use of these items will be made clear later.

A handy box for carrying supplies to field.

Putting Caps and Fuse Together (Making Primers)

Fuse is described as to sizes and properties on page 65 and caps on pages 64 to 65. Readers who are not familiar with them should turn to those pages at this point. Unroll the fuse and cut off a length that will be enough, since fuse burns about 2 feet in a minute (there are variations—see page 66).

The Fuse

Three feet will give you 1½ minutes or a sufficient time to get beyond danger under ordinary conditions. The fuse, of course, must be long enough to reach out of the mouth of the hole when the charge is in place. Measure the depth of the hole before you cut the fuse.

Warm cold fuse before attempting to bend it. It may be taken into any warm room for the purpose but should be subjected to no heat greater than 110 degrees. If for any reason you have doubts about the condition of your fuse, cut off a foot or more and try it without any cap or explosive. If it will burn properly it is all right.

Be sure to get fresh ends both for the match and to put into the cap. If fuse has been cut for some time into lengths, it is well to cut off short pieces from the old ends in order to bring fresh powder right to the tips.

Cutting the Fuse

Cut the fuse off at a very slight angle or bevel—say 30 to 45 degrees, as shown in the diagram. This slant is for the purpose of giving a little space between the actual end of the powder and the explosive material in the bottom of the cap, to enable the spark to spit into material

The only way to regulate the space is to cut the fuse as directed and let the long tip rest gently against the bottom of the cap. The spark has a better chance to ignite the explosive material in the cap when it spits from the end of the fuse than when it merely burns up to the end without any space to spit into.

The end of the fuse where cut off should be clean and free from dragging ends and threads. If it is not cut off clean, part of the covering may double over the end of the fuse in the cap and keep the spark away from the explosive, causing a misfire. Be careful to keep both ends of fuse off damp ground and out of puddles of water.

If the fuse has been mashed, or is too thick to go into the cap easily, do not peel off any of the covering. Reduce the diameter by squeezing it with the cap crimpers or by rolling it on a smooth surface under a knife blade or other smooth implement. Sometimes you can reduce it by rolling it between the thumb and finger.

The very best way to cut fuse is on a block of wood with a sharp knife. The blade can be pressed right through the fuse and will make a clean cut. Another good tool is a sharp axe, to be used on a block of wood. The method of cutting is of small importance, just so the actual cut is made smooth and even enough. If you do use other tools, have a knife with you to trim up ends that are not true. Be careful to avoid twisting, pinching or otherwise knocking the freshly cut end of the fuse about, for you may shake out the powder back far enough to cause a misfire. The powder should come out flush with end.

To get one cap out of the tin box in which they came, tilt the box up on edge till some of the caps slide forward, and then pick the cap up with your fingers. Don't attempt, on penalty of losing a hand, to take a cap out of a box by running a nail or a little stick or the fuse into it in the box. Be careful you do not drop a cap to the ground or floor.

The Cap

Turn the cap upside down, to make sure there is no dirt in it, and gently slide it on the fuse till the end of the fuse just touches the bottom of the cap. Do not ram, press or twist the end against the bottom.

Crimping

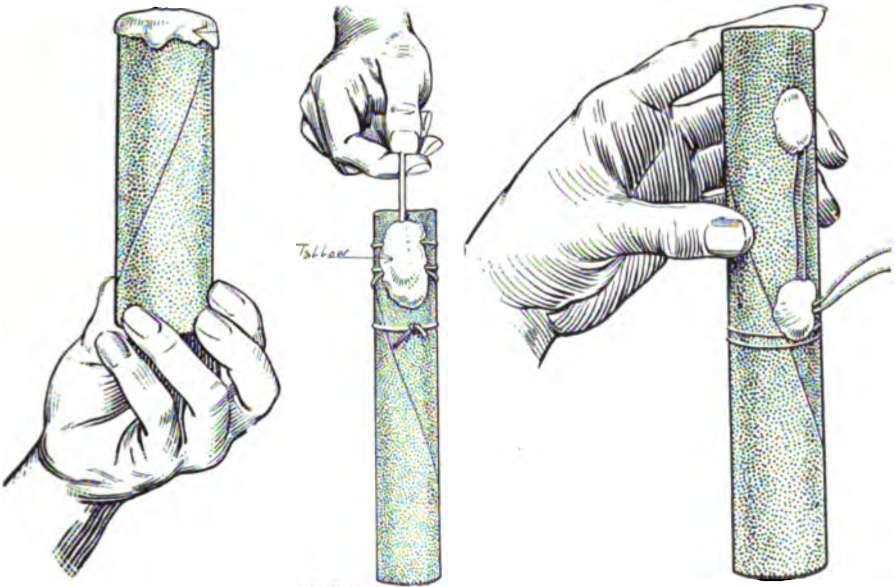
Hold the fuse with capped end up, to keep the cap from sliding off, and crimp the cap fast. This you do with the special plier-like tool called a cap crimper. The "crimp" is made by pinching the open end of the cap tight to the fuse. It should be made within the last quarter inch of the open end of the cap. Never make it toward the closed end because you might disturb the explosive material in the bottom of the cap and cause it to explode.

"Crimp" or fasten caps to fuse with a regular crimping tool. This tool does the job far better than it can be done in any other way.

Cap crimpers are supplied by

all makers of explosives. Order one or more when you buy your explosive. It is well to have an extra one about to use in case you lose one on extensive jobs.

This fastening of the fuse to the cap is one of the points in blasting where a great deal of abuse occurs. Blasters think they can take a chance with danger or with misfires, and attempt to crimp the caps some other way. Except in extreme emergency don't try to crimp a cap with anything except a regular crimping tool; but there are times when one may not have a crimper nor be in a position to wait till one can be purchased. There is a way out of this difficulty —which is to secure a makeshift crimp with something else than a crimper. It is possible to use a pair of pliers, or a small pair of pincers, and accomplish something that may hold the cap on the fuse. The best makeshift crimp is to take a fold of the cap up at one side of the mouth with a pair of close fitting, square-nosed pliers. Be careful while doing this that you do not grind the end of fuse against the bottom of cap, or pull the end back from the bottom. If the fuse should pull away from the bottom of cap a quarter inch, a misfire likely would result.



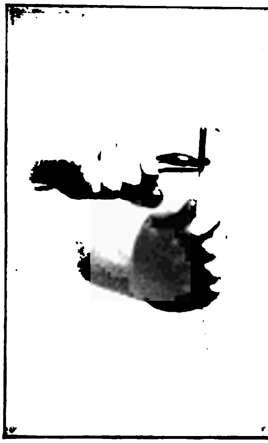
Waterproofed (tallowed) sticks ready for loading in wet holes.

Waterproofing

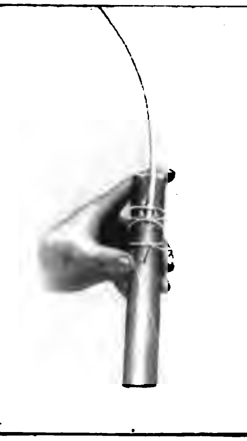
When the charge is to be placed in a dry hole, waterproofing is not needed, but in a wet hole the connections between fuse and cap must be made water-tight with tallow or soap. Do not use grease, because it may unite with the tar in the composition of the fuse cover and soften it, when the powder train will be ruined. Water in the cap will surely make it worthless.

Inserting Caps in Explosive

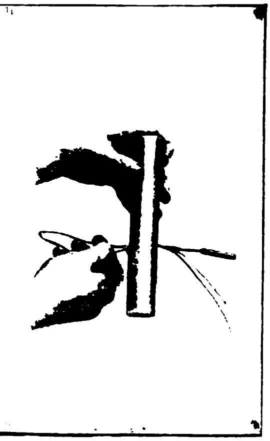
The best location for a cap in a stick of explosive for farm blasting is in a hole in the side, about an inch and a half from one end. The best position for the cap at this point is at a slant that takes it in from the side toward the center, but as near longways, or parallel with the sides of the stick, as possible.



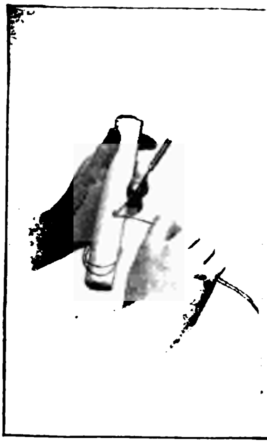
Crimping cap with the cap crimper.



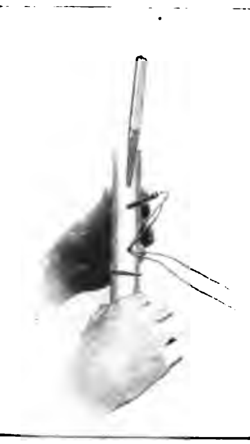
Fuse tied firmly to stick with string.



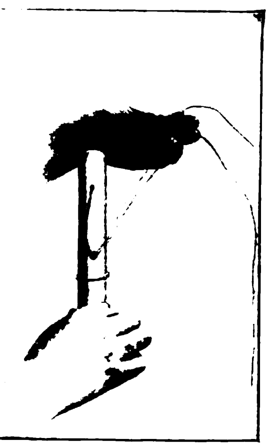
Electric Blasting—Pass the doubled fuze wires through a hole in stick of powder.



Loop the doubled end of fuze wires over end of stick.



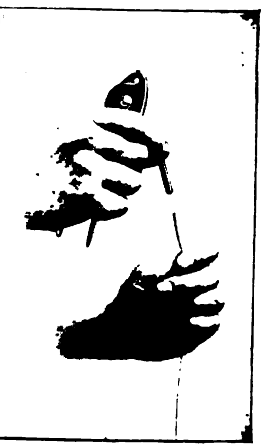
Pull loop tight, bend wires at cap, punch slanting hole in stick high up and round to side a little.



Insert cap in slanting hole to bend of wires, take up slack in wires. (Waterproof holes if ground is wet.)

In cutting fuse from roll use sharp knife.

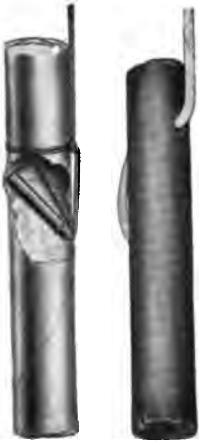
Taking one cap carefully from box.



Inserting fresh end of fuse in cap.

Position of Cap in Stick

In other words, when making the hole for the cap in the explosive, make it with as long a slant down toward the other end of the stick as possible. There are reasons for this connected with superior or inferior detonation.



Bad priming.

Another style of priming much used is to set the cap in a hole made in the end of the stick of explosive, and then to tie the paper about the fuse or wires. This is good so long as it is not damaged, but experience shows that the tamping stick often bends the fuse over sharply when the primed stick is pressed into the hole and sometimes even interferes with the cap itself. With side priming there is a cushion of the soft explosive between the end of the stick and cap. End priming always is good provided sufficient care is taken in loading to prevent disturbing or displacing the fuse or cap with tamping rod.

When all the explosive is removed from its stick wrappings, the cap must be inserted in the loose explosive. This should be done by making a hole, as in a stick. But it seldom pays to take all the explosive out of stick wrappings. Nearly always you can leave a half stick of explosive intact for the cap.

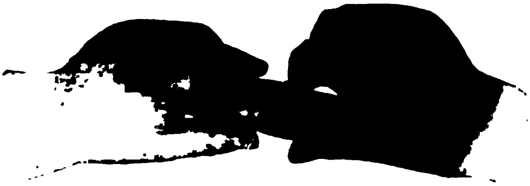
A good crimp.

Making Hole in Explosive

To make the hole for the cap use the handle of the cap crimper or a wooden punch just a little larger than the cap. The hole should be large enough to let the cap in without much pressing, but should leave no air space about the cap. The depth of the hole also is important. It should be just enough so that the entire cap can be buried in the explosive, but not any deeper. If it is deeper, the cap may be forced on down to the bottom, which will leave some of the fuse in contact with the explosive (may cause burning instead of exploding of powder), or the cap may be seated just inside the wrapping, leaving an air space at the inside end or bottom of the hole, which may lower the effectiveness of the explosive.

Fastening Fuse to Explosive

When the cap is seated in its hole in the side of the stick, the fuse will extend up along the stick past the near end. It must be tied in this position, so securely that the fuse and the cap will not be pulled back in handling or by rubbing against the side of the hole when the stick is pressed down. The best way to secure it is to wrap a strong string several times below the point where the cap is inserted, then give two or three wraps about the fuse, and pull tight and tie; or take two loops about the fuse and then several wraps about the stick.



Cutting stick in two—roll it under knife blade.

When the foregoing directions have been complied with you have a stick of explosive primed with a cap and fuse. It is ready to put in the hole in the rock or ground.

Loading Charges in Holes

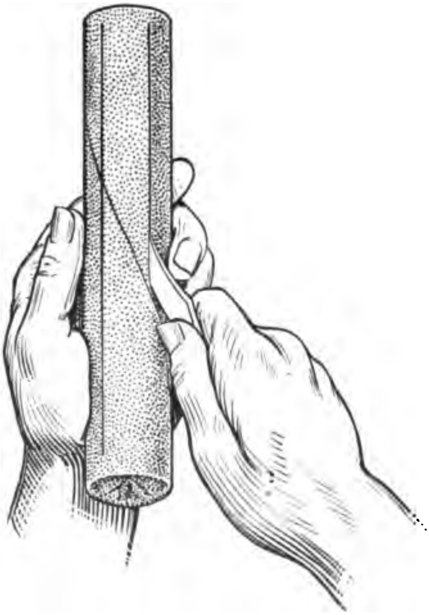
Tamping rod

You will need a tamping stick. This must be of wood, and had better be about the size of a stick of explosive, which usually will be 1¼ inches in diameter, except in case of blockhole blasting of boulders, when a smaller stick sometimes is needed to go in small drill holes. Never use a metal rod for tamping. Make sure that the hole is ready. It must be big enough to allow sticks of explosive to slide down easily (except in the case of small holes drilled in rock, when the explosive all must be taken out of the stick wrappings and crumbled and pressed into the hole). Loose stones, sharp stones and roots that obstruct the hole should be removed with a bar or spoon scraper. This work must be completed before starting to load. If obstructions fall into the hole, after some of the explosive is in place, don't try to remove it by force. Make another hole at a safe distance from the first, put in another charge and fire it.

Measure the hole with your tamping stick and judge if there is space for the required charge at the right point. Nearly always a charge of explosives should be as much on a pile as possible. If one or 2 sticks are all the explosive required, it usually will not hurt to put them end to end. But if 3 or more sticks are required, to put them end to end makes the charge too long, and places the force of the blast elsewhere than where it should be.

The tamping rod should be of wood.

When your judgment tells you that the charge should be in a more or less round bulk, enlarge the hole at the point where the charge should be made. Sometimes this can be done by scraping it out at the bottom with a toe-bar or spoon-bar. Again, if much enlarging is required, it is well to use a small amount of explosive to secure it. This is called springing. To do this prime about a quarter of a stick as usual, and push it to the bottom of the hole. Use no tamping. After it is fired wait till the hole cools, and you will find a cavity large enough for your full charge.



Slitting the paper wrapping of stick to let it swell to fill dry hole.

It is better to avoid springing holes if you can, on account of the fact that the cavity often is enlarged too much, and the surrounding earth is loosened so much as to injure confinement. (See page 55 on detonation). A great deal can be done by scraping the small auger hole out to 2 or 3 inches in diameter at the bottom and then causing the

sticks to enlarge and fill the hole solidly. To accomplish this enlargement of sticks, slit their wrappings 3 or 4 places lengthwise, from end to end. Then press them home with the tamping stick. They will expand and shorten. Four to 6 sticks in this way can be got into the full length of two.

Still another way is to take the explosive entirely out of the stick wrappings, and with the help of a tin or paper tube, such, for instance, as calendars are mailed in, funnel it down to the bottom of the hole. But neither this method nor slitting the sticks is wise in wet holes. It is true that nitroglycerin powders will stand considerable water, but the safe rule in wet blasting is to leave the sticks intact. Ammonia powders or dynamites will not stand wetting inside the paper of the sticks without damage. (Never under any circumstances cut, break, unwrap or punch holes in explosive that is frozen. You invite an explosion in your hands when you do).

When there is more than one stick in the charge, place the primed stick on top of the others—put it in the hole last or next to last—when using the cap-and-fuse method of firing.

Be sure that all parts of the charge are in firm contact. It will not do to have air spaces, or dirt, or wrinkled paper between the sticks. While all the powder likely would go off under these conditions, it will not do as much work as it should.

The sticks of explosive may fit tightly in the holes. In that case do not ram or pound them, but press firmly against them, one at a time, with the tamping stick. Press the explosive into tight contact with the sides all round, at the bottom of the hole.

Tamping

Tamping

Tamping is a necessity. The charge should be tightly confined. It is only in springing holes and sometimes in digging post holes that no tamping is advisable, and in ditching that the quantity needed is less.

When the explosive is in place at the bottom of the hole, start the tamping by rolling in some loose ground. Keep the tamping stick working up and down to seat this ground against the explosive, though make no effort to get it tight till there is a few inches or so over the explosive. An exception to this rule is in the case of blockhole blasting of boulders and ledges, when damp clay tamping should be packed solid all the way down to the explosives. The rule for the least contents of tamping that will do good work is that it should be 6 or 7 times as deep as the hole measures in diameter.

If the tamping is less than this, the best results will not be secured, hence deep holes often are necessary for the sake of confinement of charge as well as to contain the amount of powder used.

Hold the fuse to one side with one hand while the tamping stick is worked with the other hand. Rake the dirt to the mouth of the hole and be careful to get in the hole only earth—not clods, sticks, grass, etc. Be very careful not to damage the cover of the fuse with the tamping stick.

Fill the hole to the top with tamping, and make it tight. The best material for tamping is moist clay. Tamping material always is better when made *wet* enough to ball. In fact, there isn't much better tamping than water itself in the hole, when it can be made to cover the charges deeply enough. Use the heaviest earth within reach, and if it is dry, better carry some water for wetting it.

Firing

Stick the burning head of a match against the powder to light fuse surely.

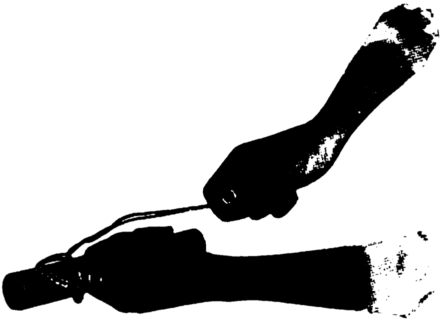
The free end of the fuse will stick out of the hole filled with tamping, say about 4 inches. Your remaining work is to set fire to the powder in the fuse, till it begins to spit continuously. Split the end of fuse with your pocket knife to make it light easily. Put the flaring head of a freshly scratched match against the powder exposed by the cut.

Preparing Charges for Electric Firing (Making Primers)

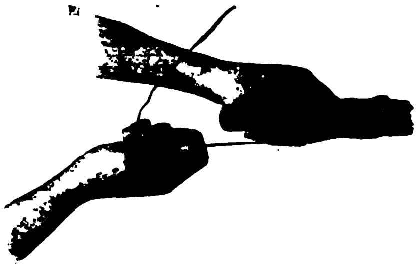
Up to this point in the directions for preparing charges the text has spoken only of caps and fuse. When the firing is to be done with an electric blasting machine instead of fuse, you must use electric blasting caps.

These come from the makers with the wires already fastened in them. (See pages 64 and 65.) They are ready to be inserted in the stick of explosive without any preparation such as ordinary caps and fuse require.

Make a slanting hole in the stick of explosive just as is described on page 44 to 46. Into this insert the electric blasting cap, letting its wires project just as the fuse does when fuse is used. Then tie the wires to the stick with a string as fuse is tied, to prevent the cap from being pulled partly or entirely out of the hole.



Bad method of fastening wires. It is better to tie them.



Bad position of cap in stick, and of cap wires.

It is a little difficult to tie the wires tight enough with a string to prevent slipping. Another way to fasten them securely is to pass the wires through the stick. To do it punch a hole straight through the stick of explosive about the middle. Double the wires about 6 inches back of the cap and pass the doubled end through this hole. Then loop the doubled ends from the other side back round the lower end of the stick. Take up the slack in the wires and you will have a sure fastening. The cap can be inserted in the stick at another point, in a slanting hole, just as described previously.

In fixing wires of electric blasting caps to sticks, avoid crossing them and avoid bending them sharply or in any manner that will break their insulating. If the insulating is broken it likely will cause a short circuit, which will result in a misfire. *Never take a half hitch about the stick with the wires.* Do not pull at the wires and the cap, because to do so may break the fine bridge wire that causes the cap to explode when the current goes through.

Load these primed sticks the same as is directed for fuse primed charges. Be careful to avoid rupturing the insulating on the wires with small stones in the hole or with the tamping rod.

The finishing of the tamping leaves two wires projecting from each hole. They must be connected with the blasting machine or other source of current with connecting wire and leading wire, in the manner described fully on pages 60 to 63. Further discussion is not needed at this point.

Some General Suggestions

In priming sticks of explosive with fuse and blasting cap, you must be careful to avoid permitting the fuse to touch the explosive. High explosives will burn like gasoline or coal-oil. They are very easily set on fire by sparks spitting from fuse. When they are burning the explosion will be very much weaker than it otherwise would be, and will give off noxious gases.

A very frequent cause of misfires is the bending, kinking and crooking of fuse. This is especially frequent when the cap is inserted in the center of the end of the stick of explosive and then carelessly forced over against the side of the hole by the tamping stick and tamping material. Keep the fuse straight, and never under any circumstances lace it through the stick of explosive. That is a sure cause of trouble.

If it becomes necessary to remove a cap from a primed stick of explosive, do it gently and carefully, and unless the cap and fuse are immediately to be inserted in another stick, destroy them both by lifting a shovelful of earth and putting the cap under the ground in the hole, after which light the fuse and go away.

It is better not to lift or carry the primed stick of explosive by the fuse or wires when it can be helped. When a practice of carrying primed sticks by the fuse is made, misfires and poor explosions will be caused, not every time, but often enough to make it wiser not to do so. The cap often is pulled back in spite of the tie string.

Where explosives that are subject to water damage are used in work that is wet, matters can be helped by making the sticks waterproof with tallow, paraffine or other suitable material. It is practicable to stop all the seams on the sticks, load and fire without delay, even with explosives that would be put out of business if the water got at the actual material instead of only at the wrappings of the sticks. Pay particular attention to waxing or tallowing the place where the cap and wires go into the stick.

When doing wet blasting, use every care to keep the outer end of the fuse from dropping into the water or from resting on damp ground. The inner wrappings of fuse and the powder train itself take up water like a blotter. On a very foggy day it is well to keep fuse in a closed box. Mist and rain of course, will damage it.

Explosives and Blasting Supplies

The catalogs of manufacturers are not intended to give all the fundamental facts about and the differences between the various explosives. To do so would take too much space. They give the trade names and the measurements and weights of sticks and boxes, demanded by purchasers, and are prepared on the supposition that blasters and buyers of explosives know what they need. This bulletin includes explanations of the names under which blasting explosives are made and marketed, outlines their properties, and makes clear the work and conditions for which each grade is intended and suited.

Explosives

Names

There are scores of different kinds of explosives made and used for blasting purposes, and many dozens of different names used for them. The most familiar name of any explosive in America is dynamite. Another familiar term is powder. Other names are farm powder, quarry powder, contractor's powder, coal powder, stumping powder, Judson powder, gelatin, blasting gelatin, R. R. P.; giant powder, blasting powder and dozens of others.

Nearly every one of the explosives designated by these names are made in several strengths, and in qualities to suit varying conditions. For this reason figures and other marks are attached to the names to distinguish the grades. In addition to this some of the names are used to designate not only one certain explosive but several widely different ones. This is particularly true of the names dynamite and powder. The selection of names in the preceding paragraph is made for illustrative purposes, and is not to be taken in any sense as a recommendation of those explosives for any purpose. The recommendations are given in detail on other pages.

Differences

All blasting explosives are not made from the same ingredients, and they differ a great deal in many other ways than in quality, as quality is generally understood. You can buy cornmeal that is good, bad or indifferent, but when you buy explosives you will find there are few which can be classed as of poor quality. Nearly every standard kind and grade is of excellent quality for some particular purpose and condition. And practically every one can be classed as of poor quality for conditions and purposes to which it is not suited.

Nor is the difference one of size of stick or grain, as the case may be, though this is one element. The main differences are ones of strength, quickness or speed of gases, sensitiveness, resistance to cold and to water, density, fumes and cost. Some explosives are suitable for wet work, and others only for dry work; some are adapted to blasting hard, tough rock, others to blasting ground only; some freeze when chilled a little; others can be exposed freely without freezing. And it should be noted that many of the better explosives of to-day have been developed during recent years and are comparatively new. The explosive to buy for any particular work is the best one on the market for all the conditions involved.

Explosive Ingredients

Black blasting powder has been known and used for several hundred years, and it is practically the same to-day as it has been for a long time. It is composed of saltpeter or nitrate of soda, sulphur and charcoal. It does not vary in strength, and varies little in other properties.

The dynamites and high explosive powders have little or no relation to black blasting powder. They depend for their explosive force on other explosive chemicals the best known of

which are nitroglycerin and ammonium nitrate. It is not necessary in this brief description to name additional explosive elements.

The first dynamite was made in Europe by mixing nitroglycerin with a light spongy earth, and packing the mixture in paper tubes as sticks of dynamite and powder are packed to-day. Nitroglycerin itself is a wonderfully efficient explosive when it can be controlled, but it is so dangerous and unstable that it must be mixed and treated to make it safe enough to handle.

As other explosive chemicals become better understood, it has been found of advantage to substitute materials that are explosive for the light earth used to absorb the nitroglycerin. And more than that, the nitroglycerin itself has been displaced to varying degrees in some of the powders and dynamites by ammonium nitrate and other materials. Few blasting explosives contain no nitroglycerin at all, but many contain only 4 or 5 per cent. of it. Each of these combinations of materials, or formula, has its own peculiarities in addition to variation in strength, all of which information it is well for a buyer and blaster to understand.

The explosives marketed as "straight dynamites" and "straight powders" are made from nitroglycerin. Those made from an ammonium nitrate base are called by many manufacturers "extra" dynamites and powders. Gelatin dynamites and blasting gelatin are nitroglycerin explosives in which the nitroglycerin has been combined with gun cotton. The various special mine, quarry, stumping, farm and other miscellaneous dynamites and high explosive powders on the market are not so named that their ingredients can be determined without a statement from their makers.

Strength and Quickness

The power of an explosive and its violence are two different qualities. The power, or direct strength, is due to the volume of the gases. If a pound of a certain explosive gives, for instance, 1,000 cubic feet of gas when completely detonated or fired, while a pound of another explosive gives 500 cubic feet and a pound of a third gives 2,000, the lifting power of each explosive will be in direct proportion to its gas volume.

But the violence of the gases depend, not on their volume, but on their speed. If they are comparatively slow in forming and in forcing their way out of their confinement they will break out large cracks and escape through them, pushing the material aside. If they are very fast or quick, they will grind and pulverize everything they come in contact with, and throw out the whole side of the confining material, but will not crack it so far.

The matter can be made clear by comparing a push with a blow of a hammer. Both may have equal power, but the effects on a block of wood, for instance, at the point where they are applied are very different. The push will move the object almost without marking it. The blow may move it, but it is sure to leave a mark of greater or less depth, depending on the nature of the hammer and its speed. A still better comparison, perhaps, is that between the blow of a sledge and of light hammer. It is possible to hit a blow of as much power or weight with one as with the other, but the material at the point where the blow lands with the light hammer will be badly dented, or maybe broken. The reason is that the light hammer moves with much greater speed.

In quarries blasters make use of these facts in order to get the rock broken out in pieces of the size preferred. When they want large pieces they use an explosive with sufficient power to break the rock, but, comparatively speaking, with a slow speed of gases; when they want small pieces and much shattering, they use an explosive of the same or greater power but with swift and violent gas action.

For each result and for each material a certain power is required and a certain quickness of the gases is best. By way of illustration, take soil blasting for tillage purposes. There is no object in violently grinding the earth at one spot while surrounding earth that might be reached is left untouched. A proper explosive for this purpose is one that will have enough pulverizing action, that will lift and shake up the soil, and that extends its effects for long distances. For an example of the other extreme, take mud-capping rocks. For this work the explosive cannot be too violent in action. The gases, backed up by the rapidly yielding wall of air behind them, must strike the rock a crushing blow in the minimum of time.

Nitroglycerin and ammonia powders and dynamites, for all practical purposes, are of equal strengths when of equal markings. The strength is indicated accurately by percentage figures.

Nitroglycerin explosives are uniformly quicker and more violent in action than ammonium nitrate explosives, and the more nitroglycerin there is in the explosive the quicker it is. The ammonia explosives are not as quick, in any strength, as the corresponding nitroglycerin explosives. Therefore a 50% nitroglycerin powder is more violent than a 50% ammonia powder, and a 20% ammonia powder is much less violent than a 50% grade.

When the object is to shatter and reduce to fine fragments the material to be blasted, the proper explosive is a quick one, while when the object is to lift and shake up the material the best explosive is a slow one. (See table on page 55, also detailed recommendations on pages 22 and 25.) But there are other factors that must be considered.

Nitroglycerin explosives resist water better than ammonia explosives, but if the cartridge wrappings are not broken or opened, ammonia dynamite or powder can be loaded in wet holes with entire satisfaction. The firing should not be delayed any longer after loading than necessary, and it is wise to plan the work so that it may be done at the longest within a half hour after loading. Storage in a damp place will weaken explosives, especially ammonia explosives.

Gelatin explosives resist water very well, and may be loaded in wet holes, or under water, with assurance that they will explode with their full power. Blasting gelatin is entirely water-resisting.

Explosives will freeze, and when in this condition are dangerous, and cannot be fired properly, if at all, with a cap of any kind. They *must* be thawed and they must be handled very carefully if they are to be used. On no account attempt to cut the wrappings, to break a stick, or to handle the frozen explosive in the ordinary way. (See pages 56 to 58 for directions for thawing.)

Regular nitroglycerin explosives are quickest to freeze. Others, known as "Low Freezing," will stand much lower temperatures without showing trouble in this respect.

Freezing

Ammonium nitrate explosives also will freeze, but not quite so quickly as nitroglycerin explosives. They too are made on both regular and low freezing formulas. The low freezing ammonia will stand more cold than the low freezing nitroglycerin.

The regular explosives will freeze at temperatures of 45 to 50 degrees. The low freezing explosives will not freeze and become solid till the thermometer gets down to at least 25 degrees, and in practice many of them can be used right out in the open without any trouble when the temperature is down to zero and below. The length of time the powder is exposed to the cold has much to do with its freezing.

The safety point for both low-freezing explosives and regular explosives is not a matter of rule, but of watching the explosive. When high explosive powder or dynamite is frozen, the sticks will be hard, and when it is partly frozen they usually will have a mottled appearance on outside of the paper wrappings. The hardness may only be in spots. When not frozen, the sticks should be a little soft all over. No explosives should be handled much, cut, punched, rubbed, broken or loaded when they are frozen. They cannot be exploded satisfactorily and such acts are dangerous.

In cold weather always use the low freezing grade of explosives, for the regular grades may freeze in the holes before they can be fired. It is a good plan to use the stronger caps, say No. 8 (see page 64) in cold weather. When a charge of explosive is chilled but not frozen it can be fired satisfactorily by a heavier impulse (blow and heat) than ordinary, such as a fresh No. 8 cap gives. The low freezing explosives do not differ in action from the regular explosives, and are just as efficient.

The gases of explosives naturally are more or less objectionable when breathed. Some of them are poisonous, others are merely disagreeable. When explosives are used out in the open the gases are taken up by the air so quickly that none of them give any serious trouble, though they do cause headaches. It is only in tunnels and deep shafts where the air is confined that the matter of fumes is important, not on farms.

Other Properties

Special explosives have been developed for tunnel and mine work, but they are not important in agricultural work. The only fact about fumes worth knowing in farm blasting is that nitroglycerin explosives either in the form of their gases or when absorbed through the skin will cause headache somewhat quicker than ammonia explosives. The so-called fumeless explosives always cost more than any ordinary dynamites and powders and are not suited to farm work. Farmers will do well to buy grades of explosives suited for their special purpose.

Appearance of Explosives

Dynamites and most high explosive powders are light-colored materials that look like fine, sticky sawdust, and they always are packed in "sticks" made with cylinders of tough paper. These sticks vary in diameter and length. The standard is 1¼ inches in diameter and 8 inches long. This is the size carried in stock by dealers and in the magazines of the makers. You can get special sizes of sticks if you need a considerable quantity, varying from ⅞ of an inch in diameter to 4 inches. Sizes other than the standard 1¼ by 8 inch may cost more per pound than the standard owing to higher packing cost.

Dynamites and high explosive powders are packed in wooden boxes containing 25 pounds or 50 pounds, as you prefer. A 50-pound box of 20% ammonia powder or dynamite will contain about 105, 1¼ by 8 inch sticks. If of 20% nitroglycerin, it will contain about 98 sticks. If of gelatin dynamite, or blasting gelatin, it will contain about 88 sticks.

A word should be said here about the cost of explosives. No quotations can be given because the prices vary in different parts of the country and from time to time. The ammonia products usually are cheapest. The cost of course follows the percentage strength, the low percentages cheaper and the high percentages dearer. Gelatin explosives cost about the same as straight nitroglycerin explosives. The special explosives for use in mines, tunnels, quarries, railroad construction work, etc., often cost more than the explosives recommended here for farm work.

In buying explosives look first to getting the one that is best suited to the work to be done, and aside from that the cheapest one. There would be no object in using a straight nitroglycerin or a gelatin explosive when one of the ammonia farm powders would do the work, for the former explosive cost much more than the latter.

To avoid "explosive misfits" it is well to consider carefully the nature of the material to be blasted, the conditions of weather, water, etc., and the results wanted. The kind of explosives to use depends on these factors. Keeping in mind the facts mentioned in preceding paragraphs, the reader will see that there is a type of explosive made for almost every condition and kind of work, and will understand why one will not suit the work of another.

As the briefest and clearest way of giving general suggestions for the type of explosive best for different agricultural work, a table follows: (Detailed recommendations are given on pages 21 and 25.)

Explosives Recommended for Different Work

Stone blasting—mudcap	Straight nitroglycerin or ammonia dynamite, 50% or 60%.
Stone blasting—undermine	To break, same as for mudcapping; to throw out, use any dynamite or powder of 20% strength.
Stone blasting—blockhole	To shatter well, any high percentage dynamite or powder; to break into large pieces, 20% ammonia dynamite or powder.
Soil blasting—for subsoiling and for tree planting	20% ammonia dynamite or powder.
Ditching—electric firing	20% to 40% ammonia explosives; (nitroglycerin is equally effective); in loose dry ground, high percentage nitroglycerin explosives.
Ditching—transmitted detonation	Straight nitroglycerin dynamite or powder, 50% strength.
Stump blasting—in medium and heavy soils, wet or dry	20% nitroglycerin or ammonia dynamite or powder.
Stump blasting—in dry sand and other light soil	50% nitroglycerin or ammonia dynamite or powder.

If you are in doubt as to the best explosives for your particular work it is well to write to the manufacturer you prefer, asking which of their grades and brands would be most suitable.

Detonation

It is well known that black powder is fired by a spark, and that dynamites and high explosive powders cannot be fired by a spark but require a shock and heat. It is not so well known that there are great differences in the nature and effect of the explosion of any powder or dynamite, due to variations in the way it is fired.

Firing, Exploding or Detonating

An explosion of powder or dynamite is the result of a very sudden creation of a great volume of gas from a smaller volume of powder. The kind and amount of gases produced by any high explosives depend on the kind and amount of shock used to fire the charge, and on its confinement.

The effect of lighting a piece of unconfined dynamite with a piece of fuse without a cap on, is that the dynamite will burn fast without exploding and make a dense smoke which has a bad smell and produces severe headaches. This is simple combustion. If the piece of dynamite is confined closely and lighted in the same way it will explode, but will give off similar bad fumes. If a weak cap is used on the fuse, or the dynamite is set off by a fall, the dynamite will be partially detonated, and explode with considerable force, but it still will give off the bad fumes and smoke. The same piece of dynamite fired with a No. 6 or 8 cap will be completely detonated, and will explode with great violence and force, even when unconfined, except by air, and will give off very little smoke.

The last-named explosion is detonation. It is produced by a violent shock in connection with intense heat. Nitroglycerin is 5 times as strong as black blasting powder when exploded by fire, and 10 times as strong when detonated. This explains the enormous force given by detonation as compared to simple explosion.

But detonation itself is no set thing that always takes place the same. There is good, or complete, or full detonation, and there is partial detonation. In case of incomplete detonation, or any detonation at a less speed than the greatest for any particular explosive, the gases formed are not what they should be. For one thing, they are more noxious or poisonous. The more powerful and severe the blow delivered by the cap, the more quickly does the chemical action take place in the explosive. It is only when high explosives detonate with their greatest speed that their maximum power is generated.

Air spaces about the cap in the stick of explosive cushion its blow and weaken detonation. It is the nature of the initial detonation of the powder right around the cap which governs the nature of the explosion of the whole charge. A blaster should understand the importance of setting up *complete* detonation in order to get the greatest amount of force out of explosives. Sometimes explosives lose as much as 20% of their effectiveness when fired with weak caps. Lack of confinement has a similar effect. Sixty per cent. dynamite poorly detonated is less effective than 40% well detonated.

When explosives become chilled it is difficult to detonate them properly with the usual cap, hence the advisability of using a very strong cap in cold weather—a No. 8. Many of the holes are frequently loaded for some time before firing, and even if the powder is soft and normal while charging, it afterwards becomes somewhat chilled in the cold ground.

Cap Means Detonator

Throughout this and other bulletins in this series, the terms caps and electric blasting caps are used in speaking of the exploders used to fire the charges of dynamite or powder, although in the field and among manufacturers the same articles are called by the terms "detonators," or "electric exploders."

Thawing Explosives

It has been pointed out (on page 51) that regular explosives chill or freeze at temperatures of 45 to 50 degrees. With the increase in the number of low freezing explosives that seldom need thawing, the necessity for doing the thawing on farms is not as frequent as it used to be.

Frozen dynamites and powders are dangerous materials, and whenever the temperature is near the freezing point for them, the sticks should be inspected before using to see if they show any of the hardness that indicates chilling. If so, handle them very carefully till they are thawed. Dynamites and high explosive powders will be a little soft to the pressure of your thumb when they are not frozen.

Frozen Explosive

Frozen explosives are dangerous because they are very much more easily exploded in the course of ordinary handling. They are more sensitive to friction and to blows of tools. The sticks may explode when dropped to the ground or floor, when sticks are broken in two, when wrappings are cut with a knife, when cap holes are punched with a stick, or when they are shoved into a hole with a tamping stick. At the same time they are so much less sensitive to the direct shock of a detonating cap that they cannot be fired properly with a cap. Therefore the rule must be laid down that frozen sticks of high explosives never must be cut or ruptured or used until they are thawed.

When nitroglycerin freezes it crystallizes, therefore the nitroglycerin in dynamite or powder tends to separate from its absorbing materials into small crystals. When the dynamite is thawed slowly with sticks lying on their sides, the nitroglycerin is reabsorbed as fast as it liquefies. But when thawed too fast, the nitroglycerin is liable to run out of the sticks before it is reabsorbed. Quick thawing will damage explosives a great deal more than they would be damaged by freezing followed by long, gradual thawing.

One type of thawer on the market.

Thawing is a dangerous operation when not done right. It probably is correct to state that more accidents with dynamite have occurred in the course of improper thawing than for all other reasons put together. At the same time proper thawing is entirely safe.

Causes of Accidental Explosions

Two of the most frequent causes of accidents while thawing explosives are in putting the sticks into water or steam, and putting them on hot stoves or stones. Water, and especially hot water, forces the nitroglycerin out of the sticks. The free nitroglycerin goes to the bottom, and explodes at the time of the first increase in heat, or first light blow. When sticks of explosives are laid on hot material the nitroglycerin also runs from the paper wrappings and drops of it fall to the stone or metal. This almost always causes an explosion. At about 350 F. degrees of heat, which is only a little more than that of boiling water, the nitroglycerin will explode without a shock

Safe Thawing

Examine your explosives a day or so before you are ready to use them, and if they show that they are frozen, proceed to thaw them in one of the following ways: Use only a *DRY* warmth. Use no temperature higher than is comfortable to the hand, or the limit may be set at 100 or 110 degrees. Use no heat of any kind that cannot be controlled with certainty. If you do this you will be safe.

Every large maker of explosives will supply thawing apparatus that is safe. Sometimes this is a double kettle arranged so that the sticks of explosives can be placed in the inside vessel, while the outside vessel can be filled with warm water and a blanket can be spread over the top. Other more elaborate thawers consist of a vessel containing watertight tubes just big enough to hold sticks of explosive, running through a space to be filled with warm water. The catalogs describe these ready-made thawers in detail.

Home-made thawers can be arranged with two buckets, one small enough to hang inside the other. Put the sticks inside the small one and warm water around the outside, in the big bucket. Another good way is to put a five-gallon can of warm water inside a barrel, or box, and pile the sticks of explosives in the barrel around the can. The top of the barrel should be covered with a blanket. Or put the water in the barrel and the explosives in a can or bucket. A small closet of course can be used instead of a barrel. A can of warm water can be set inside a magazine to keep the temperature up.

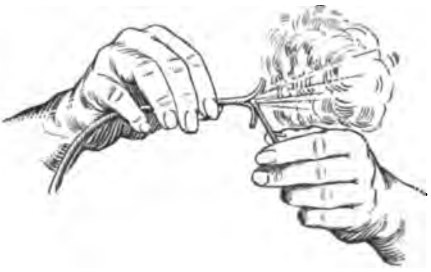
The old-fashioned manure pile method of thawing is reliable and safe, though a good deal of trouble. This consists in burying a box somewhat larger than a box of explosives in fresh horse manure, and placing inside it the box of explosives to be thawed. A foot or more of manure must cover the box, and a small pipe or tube should be inserted for ventilation. The manure must be fresh. Allow at least 10 hours to thaw a box of dynamite or powder in this way. Twenty hours is better.

Sticks on Sides

The box of explosives can be taken into any warm place that is dry, but if this is a building you must take your own risk of fire and accident. Watch the box and the sticks to see if the freezing and thawing causes the sticks to leak free nitroglycerin. If any of this leaks out of the stick and gets on the floor it must be washed up according to directions in paragraphs on storage. (Pages 67 and 68.) The sticks of explosives had better be piled irregularly rather than in tiers, for thawing. They will rise in temperature quicker in this way. They always must lie on their sides rather than stand on end.

Electric and Fuse Firing

The very best way to light fuse is to split the end for an inch or less, and stick the burning head of a freshly scratched match right against the exposed powder at the head of the split. This will light the fuse even in a strong wind.



Fuse and Cap Firing

Where there are very many fuses to light in succession, as in subsoiling, it sometimes is of advantage to use a gasoline or other torch, holding the hot flame under the fuse for an instant. Whatever the method, do not leave till you see the fuse spitting sparks and smoke swiftly and regularly. Further discussion of fuse firing, except as to its adaptations, is not needed.

Electric Firing

Farmers who have only a few stones or stumps to blast, or who are planting a few trees or doing a little subsoiling, will not need any other method of firing than by caps and fuse. Ditch blasting in ground not watersoaked demands electrical firing, while the blasting of large stumps, particularly if green, and in sandy soil, as well as the blasting of large rocks, is made easier and cheaper by electrical firing. For large amounts of almost any blasting except that of tree beds, subsoiling and very small stumps and isolated small boulders, the purchase of an electric blasting machine and the necessary wires is justified by the advantages of the electric methods of firing.

A good reel for leading wire.

Advantages

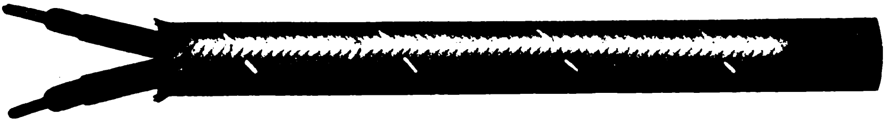
The primary reason for the superiority of electric firing over fuse firing is that several charges may be exploded at once; the different charges will increase the efficiency of each other. Thus in ditching, you can fire many charges in a row and make a perfect ditch. In stump blasting several small charges very often will take a stump out better than one large charge, and in orchard, and garden subsoiling the simultaneous blasts frequently are of advantage.

Electric firing is more certain when the charges are under water. The danger from misfires due to moisture as well as from some other cause is reduced. Should misfire occur, you are safe in going to the charges as soon as the wire is disconnected from the blasting machine. With a fuse you must wait some hours to be safe. When several charges, as for instance, several boulder blasts are to be fired, you can make one trip to safety do for the lot, instead of having to travel back and forward for each shot. Finally, the intelligent and careful use of electric firing, with its possibilities of two or more small charges doing the work of one large one, and its other economies, will save considerable explosives.

Electric Machine

All the makers of explosives supply electric blasting machines. The machines are small boxes of wood or metal, containing a modified magneto with a handle on top that you either push down or pull up, depending on the make of machine, to operate and to fire the charges. The machines are made in various sizes and capacities to fire 3, 10, 30, or more charges at once. The 10 charge machine weighs about 10 pounds. Full directions for operating and caring for the machines always accompany them.

For electric firing, in addition to the machine, you will need electric blasting caps, connecting wire and leading wire. The leading wire is copper wire large enough to carry the amount of current required for the number of charges to be fired simultaneously. It is covered with insulating material, and is made strong and durable to stand much use.



Duplex Leading Wire. (Actual size.)

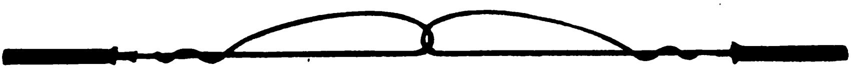
Wiring

To make the circuit from the blasting machine to and through the charges and back again, you must have two strands of leading wire. It comes from the explosive makers in single-strand and form, which must be doubled, and in what they call duplex form, which has two strands of insulated wire twisted together or wrapped together under one cover.

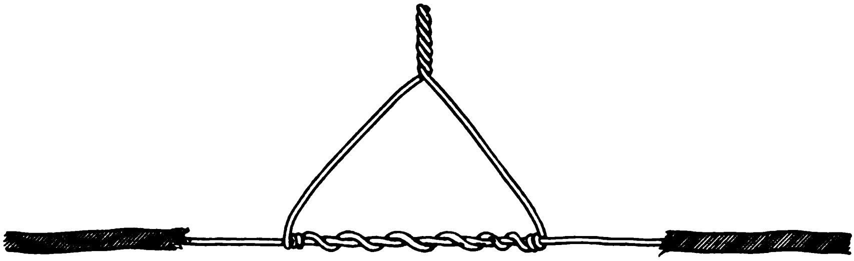
Electric Blasting Caps

The two small copper wires that are fixed in the electric blasting caps (see page 64) should be long enough to reach out of the holes. They may be bought in a variety of lengths, but 4 or 6 feet are regarded as standard. If the charges are close enough together so the wires can be connected, no connecting wire will be needed; but whenever the distance between is more, the charges must be connected, and connecting wire is the right thing to do it with. There is no particular limit for the distance between charges that may be connected for firing together, up to 25 feet or more.

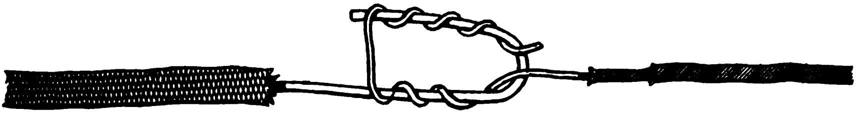
Connecting wire comes on spools.



A very bad connection—a cause of misfires.



Good connection for electric cap wires.



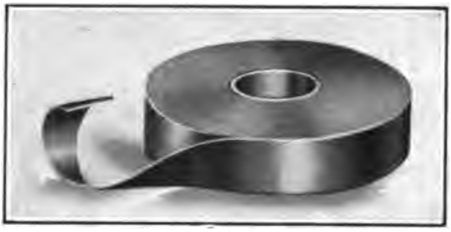
Good connection for small cap wires and large leading wire.

The diagrams in these pages will show how to make electric wire connections. Cut away the insulating on the wire ends and wrap the ends together tight. Wrap them for two inches. Looping the wires will not do. Be careful to scrape with a knife or stone the wire ends to make them bright before wrapping them together. Corroded or dirty connections are a cause of misfires.

Wire Connections

If the leading wire gets broken and must be spliced, solder the connection after wrapping the ends together, then wrap the joint with tape to

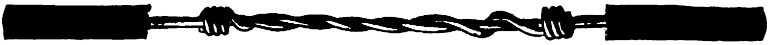
insulate it. Ordinary tire-tape is good, but a better way is to wrap the joints with special rubber tape underneath and to cover this with the tire-tape.



Tape for wrapping joints and broken insulating.

When only one charge is to be fired, connect the ends of the 2 strands of the leading wire to the 2 electric blasting cap wires and connect the other leading wire end to the blasting machine posts. The connection with the electrical blasting machine should be made the last thing before firing, after you are sure that the charges are all ready and after every person and animal is out of the way of the flying pieces.

When the blast is all connected together ready to fire, except attaching the leading wire to the machine, give the handle of the machine one or two light strokes, to make sure that it is working smoothly and to charge the magnets. Then attach the leading wires to the binding posts on the machine, making sure that both the binding posts and the wires are bright and clean where they come together. Raise the handle of the machine to its full height and push it down with speed. When the handle starts on its downward stroke, the pinion immediately clutches the armature and starts the generation of current. The current, growing stronger as the stroke proceeds, causes considerable resistance toward the end of the stroke. The current generated is directly in proportion to the speed with which the handle is pushed down, especially just before reaching the bottom. Any let up toward the bottom will cause a drop in the current and may result in misfires. Therefore, make it an invariable rule, whether the shot be large or small, to bang the handle down hard and carry the stroke with all possible speed to the bottom. Try to knock the bottom out of the box. Machines which operate by the twisting of a handle must be handled equally quick.



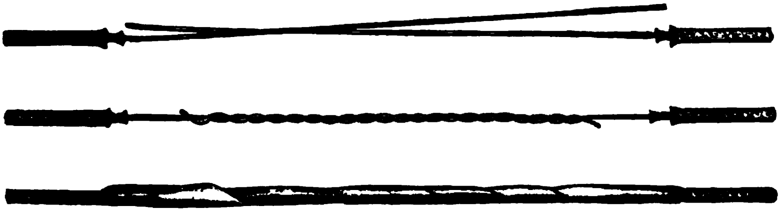
Very best wire connection, ready for soldering if need be. (Excellent for leading wire.)

When more than one charge is to be fired the different charges must be connected together. The diagrams will help you to understand how this should be done. For nearly all agricultural blasting the connection in one series is the best—that is, connecting each charge to the next one and so on until they are all joined, with one loose electric blasting cap wire from the two end charges of the series. (See diagram A and D, page 62.)

Once in a while, where the series is long and the charges are in a line, you can arrange to have the 2 loose wires at the same end of the series by making the connection, not to each next charge in the row, but to the one beyond and at the farther end doubling back and connecting the missed charge. Do not use this method where it involves many splices with connecting wire.

Connections in parallel sometimes are desirable in the case of ditches, or other extensive blasting. To make them run a piece of wire away from one leading wire strand along the lines of charges and connect one wire to each charge. Then run another similar piece of connecting wire connected to the other strand of leading wire, and attach to it the other cap wire of each charge.

But to fire charges by means of parallel connections takes so much electric current that a blasting machine cannot be used. Generally speaking, parallel



Method of wrapping wires together to make electrical joint, and of taping joint.

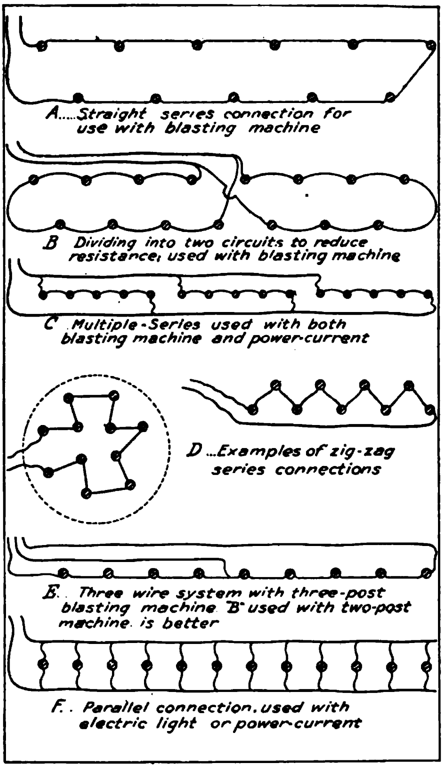
connections require current from an electric light or power plant. If your work is such that the charges cannot be connected in series or that parallel connections are desirable, it is well to communicate with an expert or authority on electricity for special suggestions and advice as to how best to fire your charges.

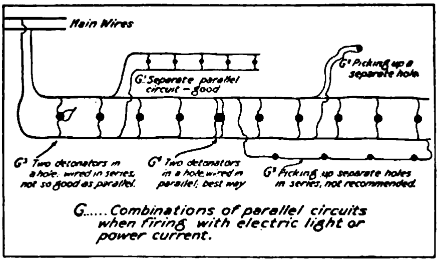
Current Required

In a bulletin of this size it is impossible to give a comprehensive statement of electric firing. But to give some idea, it can be stated that an electric blasting cap requires 1 to 1½ amperes to insure firing. This amount of current will fire one cap or many in a series. To force this amount of current through the wires requires a certain voltage, the amount depending on the size and length of all the wires, and on the joints. One bad or poorly wrapped joint will increase the resistance of the circuit more than several caps. The voltage of the current required to fire any circuit usually can be computed by an expert when the details of the wiring system are explained to him.

When charges are connected in parallel, instead of series, or in multiple series (see diagram C), each circuit requires 1 to 1½ amperes of current. That is, each cap requires 1 to 1½ amperes when connected in parallel. The voltage required, of course, depends on the resistance of the wires. A very much greater current than of 1 to 1½ amperes will do no harm; in fact it is desirable.

Electric blasting machines are constructed to give a sufficient amperage and voltage for


A.....Straight series connection for use with blasting machine
B Dividing into two circuits to reduce resistance, used with blasting machine
C Multiple-Series used with both blasting machine and power-current
D ...Examples of zig-zag series connections
E. Three wire system with three-post blasting machine. 'B' used with two-post machine is better
F. . Parallel connection. used with electric light or power-current


Main Wires
G^1 Separate parallel circuit – good
G^2 Picking up a separate hole
G^3 Two detonators in a hole. wired in series. not so good as parallel.
G^4 Two detonators in a hole. wired in parallel; best way
G^5 Picking up separate holes in series, not recommended.
G......Combinations of parallel circuits when firing with electric light or power current.

Ways of connecting up charges for electric firing.

firing properly the number of caps specified as the capacity of the machine when connected in a series. If too many caps, or more than usual wiring is connected to any machine, misfires will result. Other current can be used in place of that supplied by a machine, provided it has enough and not too much amperage and voltage. Too great a current will burn out wires without firing all the charges. Too little current sometimes will do the same, or it may do nothing. In emergencies dry cells or wet batteries can be used by skillful operators to fire a few charges, when great care is taken to have the wiring arranged for the purpose. Before attempting to fire charges with batteries of any kind, learn the amperage and voltage of their output and see that your shots come within their limits. The use of batteries is more expensive than the use of electric blasting machines.

Two post electric blasting machine—push down type.

Bare connections at the charges or back along the leading wire should be raised off the ground by stones, sticks or piles of dirt placed under insulated parts of the wires at each side of the splice. During a thunder storm, do not stand near any of the charges that have been connected. Avoid dragging the leading wire over bare or rough ground as much as possible, and particularly avoid kinking it. Be careful not to break or tear or scratch the insulating of any wires.

Do not attempt to fire through a long length of leading wire wound in a coil or on a reel. The induction, leakage or short circuit of current in the coil of wire causes the blasting machine to deliver a slow discharge, which is fatal to proper firing. Leading wire that is watersoaked or that is covered with mud will lose a considerable part of its current.

Misfires

Nearly half of the accidents noted each year in blasting operations are the result of attempting to examine misfires too soon. If misfires occur with fuse firing, stay away from the shot at least 2 hours. It is better to wait until the next day, for the spark may linger 24 hours and still cause an explosion. (See page 59.) Rock and stump misfires are to be avoided especially. When you are firing the charges electrically, you may approach the shot with entire safety as soon as the lead wire is disconnected from the blasting machine.

Misfires are due to the following named causes. The remedies for them are care in preparing the charges and in loading, the details of which are given in the proper chapters.

With cap and fuse firing, misfires are caused by having the end of fuse pulled back a little from the bottom of the cap, by crimping the fuse too tightly with a groove crimp and shutting off the spark, by damp or wet fuse, especially at the end of the cap, by defective cap, by the cap getting pulled out of the explosive, by kinked, damaged, broken or pinched fuse, by failure to light fuse. A great many misfires were never fired at all. With electric firing the reasons for misfires may be damaged wires in the hole, causing short circuits, defective caps, overloaded blasting machine, cap pulled out of explosive, bad wire connection at some point, or broken wire.

If you find after due time that for some reason the charge cannot be fired by lighting the old fuse or by sending current through the wires, you must deal with a real misfire.

The best thing to do is to put in another, lighter charge in a new hole made 6 to 12 inches of the original one. The explosion of the new charge will explode

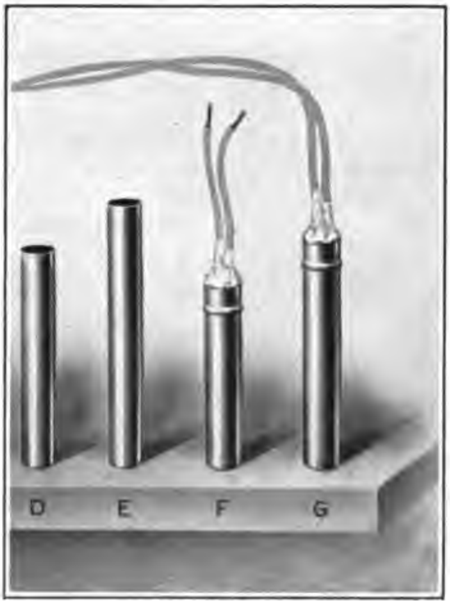
the old one. Never touch the tamping in the old hole unless you know just how deep it is, or how many inches of it there are above the charge. Once in a while the tamping may be dug out of a blockhole misfire. It seldom pays to do this in stump blasting, and never in ditching, or soil blasting. At best it is a dangerous operation. Mudcap charges can be opened and new primers inserted without danger or difficulty. This should be done by removing part of the mud at another point, and inserting a new cap and fuse, or electric blasting cap, as the case may be.

Cap (Detonators)

Blasting caps are little copper tubes closed at one end, 1½ to 2 inches long and something less than a quarter of an inch in diameter. At the bottom is placed several grains of a high explosive that is very powerful and exceedingly sensitive to heat, shock and friction. This high explosive usually is fulminate of mercury, but often is other material. They are packed in small tin boxes, open end up, usually 100 to the box.

The purpose of the blasting cap is to supply the shock and heat necessary to detonate the charge of dynamite or powder to be fired. If it were not for safety in handling blasting explosives, they all could be made as sensitive as the material in the caps. But such explosives would be impossible to handle without accident. In fact, it would be impossible to handle the little bit of explosive in the caps if it was not protected by the copper shells. Even at that caps must be kept free from jars and from heat and sparks to avoid premature explosion.

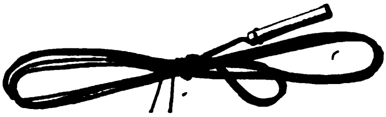
The strength of caps is carefully regulated by the makers to fire the dynamites and powders on the market. The explosive material with which the caps are loaded is such as will deliver a shock and a degree of heat of the strength and violence required. The caps are numbered according to strength. All dynamites and powders used for agricultural blasting require at least a No. 6 cap. If they are chilled a little, but not frozen, they require No. 8. It is the part of wisdom to use No. 8 caps all the time if you can get them. They give you a margin of strength should moisture or other causes weaken them in storage.



D and E are ordinary blasting caps; F and G are electric blasting caps often called fuzes.

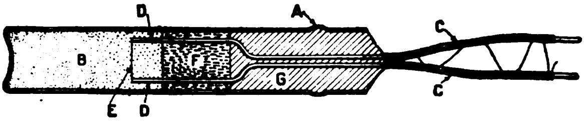
Blasting caps must be used with fuse. And before they are inserted in the stick of explosive they must be fixed to the fuse properly. (See pages 43 to 46.) It is the spark which travels down the fuse that fires the cap.

Electric blasting caps are made on the same principle as ordinary blasting caps. They have the copper tube, the explosive at the bottom, etc., but they differ in the way this explosive is fired. Instead of by a powder spark they are fired by a red-hot wire that is heated by an electric current.



Electric blasting cap or fuze.

Every electric blasting cap has fitted in it 2 small copper wires, which must be considered part of the cap. Down near the bottom of the cap is a delicate bridge of finer wire. The entire arrangement is held in adjustment and sealed by a casting of sulphur-like substance.



The interior construction of an electric blasting cap or fuze.

For fuse blasting you must use regular blasting caps, and for electric blasting you must use electric blasting caps. It is impossible to substitute one for the other. Never pull at the wires in an electric cap. It is dangerous and may loosen or throw out of adjustment the arrangement of wires inside. And never try to dig out the wires of an electric cap or to dig or to punch the explosive in the bottom of a blasting cap.

Fuse (Safety Fuse)

Fuse is used for firing black blasting powder and for firing dynamite and high explosive powders through the medium of a cap. It is made by enclosing within a covering a train of special black powder and an inflammable cotton string. The spark runs down this powder train.

Fuse as it comes in rolls.

The powder used in fuse is specially made for the purpose, is pulverized and is highly compressed by the covering of the fuse. The covering itself is made of varying materials, depending on the conditions under which the fuse is to be used. For dry work it is only enough to hold the powder in place and to keep the powder train from getting broken. For damp and wet work it is made waterproof by increasing the number of layers in the covering and by adding varnish, coal tar, as other waterproofing material.

Grades

There are many brands of fuse on the market. In buying fuse you must bear in mind the character of your work. For work that is entirely dry you can use ordinary cotton or hemp fuse with satisfaction, if it is large enough to fit a blasting cap snugly.

For work in damp ground, use a fuse in which the cotton or hemp is covered with one layer of waterproof tape or other material. This is called single-tape grade or may be known by brand name only. For work where the ground is wet, such as in stump and stone blasting in damp or wet weather, use a double-covered fuse—fuse that has two layers of tape or other material over the cotton

covering and waterproofing material added. For work where water covers the charges it is best to use fuse with three layers of tape or other material and full waterproofing. This is called triple-tape fuse or may have special brand names. When buying fuse for general farm work, it is well to get a waterproof grade, since it can be used for both wet and dry work.

Rate of Burning

Most reliable fuse burns about 2 feet per minute when in perfect condition. If it becomes damp, it burns much slower. Cases have been known where the spark smouldered in damp fuse for hours without traveling more than a few inches. Another source of uncertainty is where fuse has been pinched. It may take the spark a minute or an hour or a day to get past the pinched point.

When fuse is cold, it is hard and brittle, and may crack open when unrolled. If it gets too warm, its waterproofing material may penetrate to the powder train inside and ruin it; or the covering may first soften and then harden, in this condition breaking as though cold when unrolled. If grease is allowed on the cover it may combine with the waterproofing and ruin the powder inside.

Handling Explosives

Dynamites and powders in boxes can be hauled freely in spring wagons. You should see that no bolt heads or other metal parts project from the wagon boxes to strike the boxes of explosives. Sweep all dirt out of the wagon. Have the beds clean or covered with straw or blankets.

Go over your wagon and harness before you load dynamite to make sure they will not break down while you have the explosive aboard. Be sure you have the hitching straps or tie-ropes along, and do not leave the horses standing without tieing them securely. Break no colts while hauling explosives. If you use a motor, stop it and set the brake tight before you leave the load. In driving through a town stay away from dangerous crossings.

Keep the sticks of explosive in their original boxes until you are ready to use them. Don't have them around loose. In carrying them to the field, use a wood basket or a box and not a metal bucket. Always protect explosives from all possibility of being reached by falling sparks or from match heads or other source of fire. Rain, hot sun and the like must be kept away from explosives. Use care to lay sticks or set the boxes or baskets containing explosives where they will not fall down, be blown over by wind or knocked over by careless people or by animals. Cattle will eat sticks of dynamite, or powder, because of their sweet and salty taste. The explosive will make them sick, sometimes kill them.

Since nitroglycerin often will cause headache when absorbed through the skin it is best to wear gloves when handling the sticks. For this same reason some people punch holes for caps in the sticks with a piece of wood rather than with the handle of the cap crimper.

Caps should not be carried in the same basket or box as explosive, but should be carried separately. Take only enough along to do the work in view and carry them in the tin boxes they come in. Many serious accidents have been caused by blasters having loose caps in their pockets during work or afterwards. Sooner or later a chance jar is likely to set them off. When several caps have been taken out of the little tin box in which they come the rest will be loose and will rattle about. This should be stopped by filling up the empty space with paper.

The handling of caps is not dangerous provided you do it intelligently and with care. *Keep them safe from any jars or heat.* You can sometimes do

many foolish things with dynamite and powder without serious results to yourself, but not with caps. Letting a cap fall to the ground or floor likely will cause it to explode. For this reason you should keep the caps and explosives apart, in hauling, storing, and handling, bringing them together only at the last minute before you prepare the charge to be loaded in the hole. One cap can produce an explosion powerful enough to tear your hands off.

Handling

Electric blasting caps must be handled with the same care as regular blasting caps. All caps must be protected from dampness during handling. No trouble will be experienced if you use common sense at every turn, but thoughtlessness and carelessness in the handling of explosives will cause disaster. Bear in mind that when an accident happens with an explosive there is no time to save yourself, and no afterthought will prevent serious injury to you. Forethought is the thing with explosives. In an explosive you are handling an enormous strength. The fact that it occupies small bulk now should not interfere with your imagining it as an enormous engine with power enough to crush you easily, but under entire control if you do your part right.

Storing Explosives and Supplies

The storing of dynamites and powders on farms offers no serious problems, though it may call for some shifting of arrangements to meet proper requirements. The explosive must be kept dry. They should be kept cool. This means that any ordinary temperature of the air is all right, except that in hot weather the room where the explosive is kept should not get warmer than 80 or 90 degrees. If it is properly ventilated day and night it will not. Probably the best common storage place for explosive is in an outbuilding under the floor of which the air circulates freely and with a ceiling between the room and the roof. It should be strong, and should be provided with a lock. A responsible person should have charge of the key at all times.

The explosive should not be kept in a garret, because the hot sun beating down on a roof will raise the temperature under the roof away past the 100 degree mark.

Dampness is injurious to explosives, as noted on page 44, and dynamites and powders must be kept where moist air will not surround them. The ideal storage would be fireproof, but since this is out of the question on the average farm, the best that can be done in that respect is to guard against fire. It is well to make sure that the explosive is out of reach of any stray or malicious bullet that might be fired into it.

Look to your insurance policies and see whether they provide against the storage of explosives in any of your buildings. Store the explosive in a building not covered by the insurance.

Where large quantities of explosives are to be stored as a regular thing, or for any length of time, it is advisable to consult the makers of explosives or others experienced in their handling in regard to the location and construction of a magazine. A magazine can be set up cheaply and can be made fireproof, bullet proof, thief proof, well ventilated, dry and safe in every way. It should be built of brick. Any explosive maker will furnish plans without charge. In any case explosives should be stored at least 50 yards away from any other buildings and from roads or railroads.

Magazines

Caps

Blasting caps of any kind must not be stored with dynamite or powder. Fuse is not explosive and can be stored with dynamite or powder. Blasting caps are even more subject to damage by moisture than explosive and must be stored accordingly. Caps must not be allowed to become heated.

Deterioration

A statement of the ways in which explosive deteriorates will help in selecting a proper storage place for it. In temperatures higher than 80 degrees troubles may begin. Long continued temperatures of 90 to 100 degrees may cause the nitroglycerin to leak out of the absorbing material and to gather inside the wrapping on the lower side of the sticks, or may even cause it to leak out of the wrappings through the boxes and to the floor.

Strict watch should be kept of the sticks and the boxes to catch any such condition. If leakage occurs, turn the explosive over and reduce the temperature. Burn the empty boxes one or two at a time out away from buildings, and scrub the floor where the leakage occurred with a strong solution of sal soda. This will decompose the nitroglycerin. If it becomes necessary to destroy a little explosive without detonating it, the job can be done by immersing it until dissolved in such a solution, stirring it gently with a wood paddle.

If the sticks feel smeary it is possible they are leaking. The test is to lay them on white paper for a little while. If they are leaking they will stain the paper, otherwise not.

At a temperature of 105 degrees nitroglycerin explosives will lose 10% of their strength in a few days by evaporation. Repeated freezing and thawing is bad for explosives, especially if the thawing is rapid. Slow thawing will not damage them much. After explosive once is frozen and thawed, it will freeze much easier again.

When stored for many months explosives are liable to decomposition of some of their elements, especially if they get damp or too warm. One of the marks of this is greenish stains inside the stick wrappings. No length of time can be stated for the keeping of explosives, because it practically all depends on conditions. Under favorable conditions most dynamites and powders will remain in good shape for years. Again, a month of improper storage will ruin them and make them dangerous to handle. They develop troubles sooner in the light than in the dark.

Deteriorated explosives are likely to be dangerous—far more so than normal explosive. Keep watch over what you have in stock. Maintain proper conditions as far as possible, but if they show troubles do not hesitate to condemn them.

Shipping Explosives

The shipping of high explosives is controlled by the Interstate Commerce Commission, and the rules and regulations are very strict and rigid. Most of them are embodied in an Act of Congress of March 4, 1909, and violations are punishable with fines of not more than $2,000, or imprisonment for not more than eighteen months, or both. The person making the shipment is responsible.

A copy of the rules and regulations can be secured from the Bureau of Explosives, Underwood Building, New York City, or can be read at any freight station where there is an agent.

The rules provide that no explosives (other than certain exceptions named) shall be carried on any train, boat, trolley, or other vehicle carrying passengers

for hire, and that no explosives under deceptive or false markings or understanding shall be delivered to a common carrier; and further, that all other regulations shall be complied with.

In shipping by railroad no caps or detonators of any kind can be sent in the same car with explosives. In practice the railroads usually send them by another train, which works out to be another day in the cases of nearly all shipments. This is responsible for some delay in delivery of explosive shipments. Do not expect to have explosives come through as quickly as you would other freight.

Explosives cannot be shipped by express or by mail, but are sent by freight, the same as groceries or dry goods. The railroad company is required to place the packages in a certain way inside the car and to brace them with lumber. In case of car-lot shipments the shipper must furnish this lumber and do the bracing.

The regulations provide that railroads must have 24 hours' notice of shipment of explosives, *and that shipments must be removed from the receiving station within 24 hours of their arrival there.* The packages must be plainly stenciled with the name of shipper and consignee, and bills of lading must conform with certain specifications.

Empty boxes which once have contained explosives must never again be used for shipments of any kind. Farmers who have attempted to ship vegetables or other farm products in such boxes have unwittingly gotten themselves into trouble on account of this regulation more than once.

Danger and Safety

Modern explosives have been developed to the point where they need not be feared by anyone who handles them intelligently. Speaking in a comparative way, they may be used with no greater dangers than there is in the using of horses, mowers, traction engines, sawmills, or other farm equipment, or than there is in using shotguns or rifles.

The general use of explosives on farms is so new that many people distrust them more because of their newness than from a clear understanding of any actual dangers their use may hold. A review of what the dangers are may help users of explosives to avoid them, and may help to build up the reader's belief in the *safety* of explosives.

There is some danger in the handling and transporting of explosives, but it depends very largely on the exposure of the dynamite or powder to heat, flame, sparks, blows and friction. The directions say to keep explosives dry, to keep them at a temperature less than 90 or 100 degrees F., to keep them safe from sparks, and to avoid blows and shocks. If these directions are followed there will be few accidents.

Probably the most common cause of accidents with explosives lies in violation of some of these primary rules while thawing frozen sticks of dynamite or powder. Freezing makes the high explosive less sensitive to the simple direct shock of a blasting cap, unaccompanied, as it is, by any friction. But at the same time freezing makes the explosive more sensitive to friction in any form.

For this reason, though a frozen stick of dynamite cannot be fired properly by a blasting cap, it is very likely to be fired prematurely by a chance light blow from any object touching it, by your slitting the wrapping paper with a knife, by breaking the stick in two, or by attempting to punch a hole into it to insert a cap. (These operations are entirely safe when the explosive is normal.) If the stick is dipped in warm water or exposed to steam, or is laid on anything which is warmer than about 125 degrees, free nitroglycerin likely will leak out

and fall in drops. And one drop of nitroglycerin falling only a few inches may be exploded itself and may explode all dynamite that is near it.

Throughout the entire course of handling the explosive, from the freight station to the hole in the stone or the ground, you should remember the five cautions which will be repeated: Keep it dry, keep it cool, keep it away from sparks and flame, and keep it safe from blows and friction. Be careful—as careful as you would in driving a big automobile or a traction engine. Then you will be secure from any accidents, and explosives will be entirely safe to handle.

INDEX

Page

Accidents.....57, 58
Ammonia explosives..... 53
Amount of explosives required.....28, 29, 30
Augers.....32, 33
Blasting compared with other methods.....13, 15
Blasting Machine.....59, 62
Blasting of stumps.....7, 13, 21, 25
Blasting of stumps, lateral roots..... 23
Blasting of stumps, semi-tap roots..... 23
Blasting of stumps, When to do.....21, 22
Blasting of stumps with tap roots..... 24
Boring holes under stumps.....24, 25, 26
Boring power..... 26
Boxes of explosives..... 54
Breaking sticks of explosive.....45, 46, 47
Burning stump pieces.....36, 37, 38
Burning stumps.....13, 16, 17, 18, 19
Buying explosives..... 54
Caps and fuse, Putting together.....42, 45
Caps, Blasting.....56, 64
Caps, Positions in sticks.....44, 46, 49
Capstan pullers..... 14
Carrying explosives.....41, 66, 67
Charges, Depth for.....22, 23
Charge, What it is.....41, 49
Charpitting.....17, 18
Chilled explosive.....53, 56, 57
Choice of methods..... 13
Clearing away sprouts..... 39
Clearing land, Advisability of..... 4
Clearing land, Methods of, Compared..... 13
Cold weather blasting.....21, 22, 53, 56
Connections, Wire.....60, 61, 62
Cost of explosives..... 54
Cost of stump removing.....6, 7, 21, 32
Crimping caps.....42, 43, 44
Crops, Increase of..... 6
Crops, Kinds of for new ground.....39, 40

Page
Cultivation, Ease in 6
Current required to fire charges 62
Cutting sticks of explosives 45, 46, 47
Danger 69
Dead stumps 13, 23, 28, 29
Depth for charges 22, 23
Derricks 36, 40
Deterioration of explosives 68
Detonation 55
Detonators 56, 64
Differences in explosives 51, 54
Digging stumps 12, 17
Disposal of stumps 13, 36
Donkey engines 15, 20, 36
Dry ground 23, 31
Dynamite, General properties of 51–54
Dynamite, Grades and types of 51, 52, 54
Dynamite, Kinds to use 31
Dynamite, Low freezing 53
Dynamite, Names and brands of 51–55
Dynamite, Removing wrappings from sticks of 41, 42, 46, 47
Electric blasting caps, Description 49, 56, 60, 63, 64
Electric blasting caps, Inserting in sticks 44, 45, 49
Electric blasting, directions for 23, 24, 25, 27, 49, 58
Electric boring machines 26
Electric firing, Advantages of 59
Electric firing, Machine for 59–62
Electric firing, Wiring required for 60, 62
End priming 46, 49
Engines 15, 20, 36
Explosive ingredients 51
Explosives, Frozen 53, 56
Explosives, General properties of 51, 54
Explosives, Low freezing 53
Explosives, Names of 51, 55
Explosives, Quickness of 52
Explosives recommended 31, 55
Explosives, Removing wrappings from sticks of 46, 47
Explosives required, Amount per charge 28, 29, 30
Explosives, Strength of 52, 53
Explosives to use 31, 52
Finishing new ground 39
Fireplace wood 36

Page
Firing, Electric . . . 23, 24, 25, 27, 49, 58, 59
Freezing of explosives . . . 53, 54, 56
Fuel value of stumps . . . 36
Fumes . . . 54
Fuse and caps, Putting together . . . 42, 45
Fuse cutting . . . 42, 43
Fuse, Fastening to sticks . . . 44, 45, 46
Fuse length . . . 42
Fuse, Lighting . . . 49, 58
Fuse, Safety . . . 65
Fuzes . . . 49, 64, 65
Fuzes, Priming with . . . 45, 49, 50, 58
Gases . . . 54
Gin poles for piling . . . 36, 37, 39
Green stumps . . . 13, 23, 28, 29
Ground, Dry . . . 23, 31
Ground, Nature of . . . 12, 15, 31
Ground, Wet . . . 21, 22, 38
Handling explosives . . . 66
Hangfires . . . 27, 50
Headache . . . 35, 54, 66
Hints, General . . . 34
Holes for caps in sticks . . . 46
Holes in ground and wood for charges . . . 24, 25, 26
Idaho charpitting . . . 18
Ingredients of explosives . . . 51
Labor required . . . 32
Lateral-root stumps . . . 8, 9, 24, 25
Length of fuse . . . 42
Lighting fuse . . . 49, 58
Loading charges . . . 22, 27, 28, 47, 48
Logs, Splitting . . . 35
Loss from stumps . . . 6
Low freezing explosives . . . 53
Magazines . . . 67
Making holes for charges . . . 24
Methods of clearing compared . . . 12, 13
Misfires . . . 27, 50, 63
Names of explosives . . . 51, 55
Nature of ground . . . 12, 15, 31
Nitroglycerin explosives . . . 53
Packing of explosives . . . 54, 68
Parallel connections of electric wires . . . 61

Page
Pasture land 4, 39
Pilers 36, 37, 39
Powder, Best to use 31, 55
Powder, Grades and types of 31, 51, 52, 55
Powder, General properties of 54
Powder, Low freezing 53
Powder, Removing wrappings from sticks of 46, 47
Power boring 26
Primers, Making 42, 45, 49
Priming sticks of powder 42, 44, 45, 46, 49
Profit in stump removal 6
Protection of explosives 41, 66, 67
Pullers 14
Pulling stumps 13, 19, 20, 21
Punching sticks for caps 45, 46
Quickness of explosives 52
Rod tamping 47
Roots, Nature of 8, 9, 24, 25
Rotten stumps 10, 35
Rotting of roots 10
Safety 69
Safety fuse 65
Season to blast stumps 21, 22, 38
Season to pull 14, 15
Selling stumps 36
Semi-tap root stumps 8, 9, 23, 24, 25
Series wire connections 62
Shipping explosives 68
Side priming 44, 49
Slitting stick wrappings 27, 46, 47
Soil auger 33
Soil blasting 21, 22, 38
Soil conditions 10, 13, 14, 21, 22, 31, 38
Soil, Dry 23, 31
Soil, Nature of 12, 15, 31
Soil, Wet 21, 22, 38
Spoiling of explosives 68
Sprouts 10, 39
Standing trees 34
Sticks of powder, Appearance and size of 54
Sticks of powder, Breaking or cutting 46, 47, 48
Storing explosives 67
Strength of explosives 52, 53

Page
Stump blasting.......7, 13, 21, 25
Stump disposal.......13, 36
Stumps, Age of.......10, 13, 28, 29, 30
Stumps, Kinds of.......8, 9, 24, 25
Stumps, Lateral root and semi-tap root.......8, 24, 25
Stumps, Nature of.......24, 25, 30
Stumps, Tap-root.......8, 23, 24, 25, 29, 30
Tamping....... 48
Tamping rod....... 47
Tape....... 61
Tap-root stumps.......8, 9, 24
Test loadings.......30, 31
Thawing explosives.......56, 57
Time required for blasting....... 32
Tools.......21, 32, 33
Traction engines.......15, 21
Violence of explosives.......52, 53
Water in ground.......10, 27, 38
Waterproofing charges....... 44
Weakening of explosives....... 68
Weather conditions.......10, 21, 22, 31, 53, 56
Wet soil.......10, 38
Wire connections.......60, 61, 62
Wiring for electric blasting.......59, 62
Wrapper removing from stick.......46, 47

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THE USE OF EXPLOSIVES IN AGRICULTURE

BY

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FOREWORD

The writer has received many letters asking questions about the use of explosives on the farm. These questions may be classed as a rule under the head of "How explosives are used" and "Does the use of explosives benefit the soil?" Answers to the first class of questions may be found in books on the manufacture and use of explosives.

This paper is an attempt to answer, in a general way, the most common of the questions of the second class.

The writer has had occasion in mining and engineering work, in earlier life, to use all kinds of explosives. In later years as a chemist he has endeavored to invent explosives that would combine safety with efficiency and has secured patents in various countries. Recent years have been given to the geology and chemistry of the soils, and the writer believes that deep plowing and cultivating of the soils by means of explosives is almost as great a step forward as irrigation. He believes that the time has come when explosives should be made **especially for agricultural uses**, explosives that will be **safe to use, safe to handle, and safe to store on the premises.**

If this paper stimulates in any degree the study of soils, or encourages the farmer to use freely explosives made especially for his purposes. it will have served its purpose.

THE USE OF EXPLOSIVES IN AGRICULTURE

Agriculture has been and will be the primary basis of wealth, for the solid and substantial wealth of the nation comes from the soil. The soil is the principal asset of the nation, the one that not only clothes and feeds us, but the one that will if properly cared for **improve with age.** It is a precious inheritance that should be jealously guarded and cared for, yet it is neglected, abused, and misunderstood.

Nearly all the best land of the country has been taken up and the question of the present and of the future is not one of greater acreage, but of greater production per acre. As lands rise in value the greater the need of a knowledge of all the factors governing plant growth, and of the best instruments to use in putting the soil in the proper condition. This knowledge of intensified farming, or the new agriculture, is advancing with rapid strides keeping pace with the latest discoveries in transportation and power.

Agriculture is the oldest of all the arts of civilization, and as early as 95 B. C., Cato said: "Plowing the land means rendering the earth porous and friable, which must tend to increase its productiveness."

Ages have passed away, yet many persons still merely scratch the surface of the soil instead of plowing deep, content to live on the thin frosting of their cake.

Agriculture in its strictest sense refers to the cultivation of the soil for the purpose of **increasing the growth** and **yield** of valuable plants. Anything therefore that does increase the growth and yield of plants is of value to the farmer whether it be a machine, a fertilizer, or an explosive.

Man, after all, can only **assist Nature** in every way, and one of the best ways is to stir the soil deeply, keeping it in the proper physical and hygienic condition. In order to attain this end one must have some definite knowledge of the physical and chemical character of the soil and its hygiene in order to secure good crops. He must not look at the soil without seeing, or walk over it without thinking.

The object of this paper is to call attention to some of the fundamental, or a, b, c, principles that underlie the care of the soil, and explain why it pays to use explosives on the farm. The aim of the farmer is to produce large quantities of saleable produce with the least amount of labor, invested capital, time, and acreage. Explosives properly used in many ways and for many purposes mean less labor, less invested capital, less time, more acreage cultivated, and an increased production per acre.

The use of explosives places in the hands of the farmer the means of maintaining and increasing the fertility of the soil, and in many cases to make soils productive that before were barren. An explosive is a labor-saving device that reduces the cost of production, increases the crop values, saves time and money, increases the acreage that can be tilled, increases the yield per acre, improves the physical character of the soil, and increases the value per acre of the land. It is the latest up-to-date farm hand, one full of concentrated power and condensed strength, and one ever ready and willing and able to do the work assigned. Their broadest use and greatest value in agriculture will ever be for stirring, losening, aerating, and draining the soil, or in other words, DEEP PLOWING.

THE PROBLEM OF THE FARMER Few realize what even ordinary plowing means. The weight of an acre of average soil one foot deep is about two thousand tons. The art and science of soil management is to so manipulate this 4,000,000 pounds of raw material at an expense of from ten to twelve dollars an acre as to produce the greatest quantity of profits and still leave the soil in the best condition for future crops. If the farmer only plows 6 inches deep he must still turn over 1000 tons of soil per acre, and if only 3 inches deep there is still 500 tons per acre to be handled. Multiply this by 5 or 10 acres or more and it is heavy work for man and beast, and requires a correspondingly heavy outlay for heavy horses, heavy harness, and strong plows. With all this expense land is rarely plowed one foot deep, and with the best subsoil plows, expensive to buy and expensive to operate, few stir the soil as deep as 18 inches. With an explosive, however, the soil is readily stirred to a depth of five or more feet without tying up capital in machinery that is seldom used, costly to operate, and rapidly decreasing in value.

THE CHARACTER OF SOILS

In order to understand the effect of cultivating land, of the relative benefit of shallow plowing, deep plowing, and using explosives, one must have definite ideas about the character and composition of soils. Many seem to think of soils only as a mass of ground-up minerals which are more or less dissolved in water, forming a mineral soup on which the plants feed, and that when the valuable minerals are all dissolved the soil is worn out and exhausted unless mineral food is replaced by the fertilizers used.

This is the old superficial view of soils that has led to endless errors, expense and loss. It does not look deep enough into the make-up of the soils. It only considers the chemical composition of the soil particles which **are remarkably uniform and similar in all soils,** and is of minor importance and overlooks the physical character of the soils **which vary widely and is of the utmost importance.**

WHAT SOILS ARE

The physical character of a soil means the size of the particles, or grains, of which it is composed; the size and arrangement of the pores, voids, or spaces between the soil particles which hold the soil atmosphere; and the kind or condition of the water contents of the soil. If the physical condition of the soil is good crops will flourish. If the physical condition is bad crops will not grow, no matter how much mineral fertilizer is fed to it. Barnyard fertilizers help mainly for the reason that they improve the physical condition of the soils.

ENOUGH MINERALS IN THE SOIL Minerals exist in nearly every soil **in sufficient quantities** to supply the plants with mineral food. One of the greatest steps in advance in agriculture in late years is the realization and recognition of the fact that practically **all soils contain sufficient plant food for good crop yields** and that **this supply is indefinitely or permanently maintained,** and that the productiveness of a soil **depends more upon its physical condition** than it does upon its chemical composition.

NORMAL SOILS Normal soils, no matter whether they are the rich black loams of the Mississippi valley or the sandy soils of the Pacific Coast, are really and finally nothing but **mixtures** of fine gravel, coarse sand, medium sand, fine sand, very fine sand, silt, and clay. In the new agriculture these names are not used in a general way, or in a general sense, but with precise and scientific limitations.

The fine gravel means any particles not larger than two (2) millimeters (2mm.) or smaller than one millimeter (1 mm.) in diameter. Very fine sand means all particles from one-quarter to one-tenth millimeter (0.25 to 0.1 mm.) in size and so on. These sizes seem very small to us, but are relatively coarse and large when compared with the feeding rootlets of plants. The following tables show the standard size of the soil grains or particles, and the immense number of particles in a single gram of pure soil:

				Number of particles
Fine gravel	2.000	to 1.000	mm	252
Coarse sand	1.000	to 0.5	mm	1,723
Medium sand	0.5	to 0.25	mm	13,500
Fine sand	0.25	to 0.1	mm	132,600
Very fine sand	0.1	to 0.05	mm	1,678,000
Silt	0.05	to 0.005	mm	65,100,000
Clay	0.005	to 0.000	mm	45,000,000,000

IMPORTANCE OF THE SOIL PARTICLES

The importance of the soil particles in any soil mass lies in the total surface area of all the particles. The greater the surface area of the particles the greater the amount of water held as a film on their surfaces; or in other words, the greater the amount of feeding ground presented for the hair-like rootlets to feed on. To appreciate what is meant by surface area take this illustration: A rock 3-ft. cube, or one cubic yard, exposes 9 square feet of surface on each of its six faces, or a total of 54 sq. ft. Divide it into 1-foot cubes and the surface is increased to 162 square feet. Divide it into 1-inch cubes and it presents 1944 square feet, or nearly 1-20 of an acre of feeding surface for the roots. A single cartridge of explosive can easily convert several yards of compact soil or useless hardpan into half an acre of new feeding ground.

The immense area exposed to the feeding roots of plants by breaking up the compact soil is realized when one thinks of the surface area of the soil particles in field soils in square feet. The particles present in a single gram of soil have been calculated as follows:

One Gram of	Particles
Sandy loam contains	6,485,000,000
Fine sandy loam	6,902,000,000
Silt loam	9,639,000,000
Clay loam	16,371,000,000
Clay	19,525,000,000

VOIDS

A soil must be porous, that is have enough voids or air spaces in it to permit the entrance of air and moisture in proper proportions in order that the plants may be properly supplied with food and water, and that the sanitary condition of the soil may be kept good, if the crop is to have a vigorous and healthy growth. These voids may seem infinitely small, but their importance is large and must be taken into consideration by the cultivator of the soil. The soil particles are not in actual contact, but are separated by thin films of moisture or by actual air spaces. Their size may be judged by the size of the soil particles. The size of the voids determine the amount and circulation of the soil atmosphere, the circulation of water, and the soil's capacity for retaining moisture of the right kind, and in the right proportion for plant growth.

If the particles are fine as in the clays and silts, the voids are too small. If the particles are large as in the sands the pore spaces are large. A clay soil has more total pore space than a sand, but the individual voids are too small for the proper aeration of the soil and proper moisture conditions. The benefit of the explosive is in creating voids that permit aeration and water circulation. The percentage of pore space voids by volume is as follows:

	Per cent. of Pore Space by Volume.
Clean sand contains	33.50
Coarse sand	40.00
Medium sand	41.80
Fine sand	44.10
Sandy loam	51.00
Silt loam	53.00
Clay	54.00

By means of explosives larger pore spaces are created in the compacted soil and to depths greater than can be obtained by other means.

SOIL ATMOSPHERE Plants must have air to breathe, just as much as animals, and need a well-ventilated soil as much as we need well ventilated rooms to live in. There must not only be a good soil atmosphere, but there must be a free connection with the air above the soil.

Air and water will not penetrate a soil that is packed too close. It would require a volume to mention all the effects of air circulation in the soil, but a few of the elementary facts may be mentioned. The oxygen of the air penetrates the soil working many chemical changes of the utmost importance to plant growth, by oxidizing soil materials.

The soil atmosphere contains more carbon dioxide, or carbonic acid gas, and more nitrogen than the air above ground. The carbon dioxide furnishes the carbon for the woody portion of the plants, of the starches, sugars, and other hydrocarbon compounds. The diffusion or circulation of this necessary gas is less where the voids are too small, where the drainage is poor, and where water percolates slowly. Soils have the power of absorbing many kinds of gases that are ever busy in chemical work. This property properly depends upon the physical condition, porosity, temperature, and moisture contents of the soil. Pressing, compacting the soil, or too much water, decreases the amount of valuable and necessary gases absorbed. The diffusion of air, carbon dioxide or absorbed gases through the voids is slow and cultivation or **loosening up the soil** is necessary in order to secure proper aeration. The air and gases absorbed aid the plant roots in dissolving and assimilating the plant food. Unless air freely enters the soil and is **frequently changed** nitrification cannot go on, hence the necessity of frequent plowing, raking, spading, and stirring the soil; but only an explosive can stir it to its depths.

The importance of the soil atmosphere is shown by the fact that less than 10 per cent. of the growth of tree, crop, or vegetable, comes from the soil itself, and over 90 per cent. of it comes from the soil atmosphere and moisture. Burn a plant and the ash, or mineral portion, is left. Only the purely mineral part of this ash is from the soil particles, the carbon, hydrogen, oxygen, and nitrogen that make up the bulk of the ash and of the plant comes from the soil atmosphere and moisture. The soil atmosphere is of many times greater importance than the mineral contents of the soil. This is why deep aeration by explosives often gives remarkable results in the form of bumper crops, after expensive fertilizers have failed. An explosion thoroughly loosens the soil admitting air, and water vapor and the air is brought into direct contact with soil particles that had been previously shut away from it, giving a fresh supply of plant food. Many soils are extremely heavy, being composed of the fine particles of silt and clay. Such soils are easily puddled and compacted, becoming impervious to air and water, a condition easily changed by use of an explosive.

WATER IN THE SOIL Water is the most important and necessary of all the minerals in the soil. It is common knowledge that water is the carrier of the mineral foods, the dissolved elements and the absorbed gases, but few seem to realize that water is present in soils in several physical conditions, each serving a special purpose, so that one may properly speak of different **kinds** of water as existing in soils. GRAVITATIONAL WATER is water that is free to move through the soil pulled downward by the force of gravity. It is water present **in excess** of the amount which the soil is able to retain, and is injurious to plant life and must not be allowed to remain long in the soil.

CAPILLARY WATER is that which is retained **after** the gravity water has drained away, and which is capable of rising **upward** or spreading laterally through capillary action and seemingly in opposition to the action of gravity. The capillary capacity of a soil depends upon its texture and physical character and organic contents. It is controlled largely by the size of the voids. This water is the principal source of plant food and is the seat of important chemical and biological changes.

Irrigation or rain furnishes gravity water which drains away leaving the capillary water above it. Gravity water stored in the subsoil and depths below maintains the supply of capillary water to the zone of root growth.

The optimum, or best, amount of capillary water varies with each kind of soil, ranging from 4 per cent. for some sandy soils to 20 per cent. of the weight of a dry clay soil. Where plants are growing the movement of this kind of water is not only upward but also towards the living roots from all sides. The rate of capillary movements varies with the kind of soil. For fine sands it is 2.3 pounds per square foot per day of 24 hours, and for clay loam is 2.0 pounds.

WATER VAPOR The air that fills the pores or voids of the soil contains water vapor even after the capillary water is exhausted, and this water vapor is as important and necessary in maintaining plant life as the moisture in the air of the rooms we live in is necessary to us.

FILM WATER Drop a marble into mercury and it comes out dry. Drop it into water and it comes out wet with a very thin film of water that is very hard to remove by rubbing. It cannot be driven off except by heats greater than are found in soils below the surface. **Hygroscopic water** is the moisture that condenses upon the surface of the soil particles when the soil is allowed to become air dry. The very driest road dust has some of this kind of water clinging to it. The hair-like feeding rootlets come in close contact with the film water without being excluded from the necessary air supply. Under ordinary climatic conditions loams and clay contain as much as from 4 to 8 per cent. of their weight of this hygroscopic or film water. The success of dry farming is largely due to maintaining this kind of water in the soil.

The right amount of film water and water vapor, and its maintenance by capillary water, united with air in the voids is the key to success in modern agriculture.

STORAGE OF WATER IN SOILS The diameter of the soil particles and the amount and form of the voids determine the storage capacity of a soil, and the amount of water that can pass through it in a given unit of time. The storage capacity in round numbers is about two feet of water to five feet of soil. Sand and sandstones lying below drainage outlets may contain 38 per cent. of their volume of water and become storage reservoirs of great capacity. Clays range from 20 to 50 per cent. of their dry weights in stored waters. The maximum water capacity, or saturation of a soil depends upon the total pore space as shown in the following table:

	Per Cent. at Saturation.
Dune sand	40.5
Coarse sand	39.5
Fine sandy loam	38.0
Light silt loam	38.0
Clay	54.5
Humus	333.3

The optimum or best amount of moisture where the soil works the best is where it does not puddle, but gives the desired **granulation** or crumb structure known as **good tilth,** without hard clods and easily pulverized by raking.

WORK OF WATER Water does mechanical work in carrying down dust, smoke, gases, and dissolved mineral and organic matter into the soil. It cuts clods into pieces and breaks up and fines the soil. It also is active in many ways chemically, the most important being the soil solution.

SOIL SOLUTION The waters in the soil absorb gases and hold in solution mineral, animal and vegetable matter. This soup is absorbed by the feeding rootlets and passes through the plant circulation and is the blood of the plant. The excess of water in the soil solution is evaporated from the leaves. The quantity of water drawn from an acre this way is as follows:

	Pounds of Water.
Wheat exhales	409,832
Clover	1,096,234
Sunflowers	12,585,994
Grapevines	730,733
Cabbage	5,049,194
Hops	4,445,021

WATER TABLE This is the level at which water stands in the soil, and may be permanent or temporary. If it is only two or three feet from the surface there is not enough dry soil and soil atmosphere for the roots to grow in and they either drown or the plant is sickly. If too deep not enough water rises by capillary action and the plants suffer from drought unless deep-rooted. The height of the water table depends upon the physical character of the soil, the character of the subsoil, or the presence of hardpan or rock too near the surface. Few vegetables or trees tolerate having their roots permanently soaked in water any more than a person can keep well if his shoes and stockings are constantly wet.

EVAPORATION The sun is the greatest of all pumps. Evaporation takes place largely from the water vapor coming out through the slow process of diffusion. A dry surface mulch of straw, dust, or loose soil conserves the moisture below by preventing evaporation. The water in the lower portion of the soil can only be lost by being raised first to the surface to be evaporated.

LIFE IN THE SOIL A fertile soil fairly hums with life and activity. Myriads of microscopic organisms live in the soil. Some are scavengers, some are busy breaking down minerals into plant food, and others are chemists extracting nitrogen from the air and organic material making it available as food to the plants. The success of agriculture also depends a great deal upon bacteria and other lowly forms of life in the earth. Without the bacteria the soil would yield poor crops. Without them the soil would soon be clogged with the remains of dead plants and animals. The process of nitrification does not take place unless the soil has free air and water vapor. It cannot take place unless the soil is in and is kept in the right physical condition.

WARMTH NECESSARY Soils must be warm in order to produce crops. The essentials for the good growth of crops are favorable light, air, warmth, and moisture conditions. A compact soil loses heat more rapidly than a loose one, and plowing with explosives warms the soil to greater depth. The coarser the soil the warmer it gets and the better it holds the heat. The bacteria are inert in cold soils and active in warm soils. Wet soils are cold, and draining a water-soaked soil warms it.

TEXTURE This term takes into consideration the size of the soil particles and of the voids, and therefore of the capacity of the soil to retain moisture, hold sufficient atmosphere, and absorb gases. Coarse textured soils hold less water and more air than soils of fine texture, but the kind of moisture is that most useful to the growing plant. Where soils have good texture they are granulated or crumbly, the air spaces are in good proportion, the kind of moisture right, the warmth stimulating, and the proper chemical changes are taking place. The following table shows the influence of texture upon the per cent. of moisture contained:

Coarse sand	containing	4.8%	of clay holds	4.6%	capillary	moisture
Medium sandy loam	"	7.3%	"	11.8%	"	"
Fine sandy loam	"	12.6%	"	11.8%	"	"
Silt	"	10.6%	"	12.9%	"	"
Silt loam	"	17.7%	"	26.9%	"	"
Clay loam	"	26.6%	"	32.4%	"	"
Clay	"	59.8%	"	46.5%	"	"

FEEDING ROOTS The feeding rootlets, like slender hairs of microscopic size spread everywhere through the soil. They are always moving, pushing forward, and absorbing their food from the soil waters and soil atmosphere, and ever increasing in size and strength.

TOXINS Plants not only absorb food but also excrete material that makes the soil unsanitary, poisonous to the plant that secretes them and to other plants that may follow. Fortunately some plants feed upon the toxins excreted by others, hence the benefit of rotation of crops. Toxins are definite chemical compounds and are especially apt to form where the aeration is deficient or the soil too wet. Nearly all of the so-called **wornout soils** are soils **poisoned** by prolonged production of one crop, or else they are soils in poor physical condition, abused and neglected soils. Nothing helps such soils so easily as the use of explosives to bring up fresh material from below and to admit air to oxidize the toxins into harmless material, or even into new plant food.

CULTIVATING Given the proper physical and hygienic conditions in the soil, and crops will as a rule find present all the plant food they desire or need. A natural soil is rarely a perfect soil, and few soils are in the proper condition to receive and retain moisture properly. Plowing and cultivating are chiefly beneficial on account of their effect upon the soil texture, upon the aeration, moisture and warmth. The purpose is to break up and fine the soil more than it is to keep down the weeds. Shallow plowing is sufficient to admit some air, and to form mulches and check evaporation, but from all that has been said before, this is not enough. The ground should be stirred and ventilated **several feet** in depth, something beyond the ability of the plow and only to be accomplished by the use of explosives.

THE SUBSOIL The distinction between the surface soil and the subsoil, especially in the Pacific coast regions, lies very often only in the color and texture, the composition being very much the same.

Generally the subsoil is soil in the process of making, or raw unfinished soil ready through aeration to weather rapidly into good soil. Where the subsoil is wholly different from the surface soil in composition, as clay or sand below loam, it requires careful study and consideration.

HARDPAN This is mainly a secondary product formed in the soil through local conditions, and is generally due to a checking of the water circulation and lack of aeration. All waters which percolate through the soil soon dissolve materials of various kinds. A change of temperature, a checking of the water movement, or other causes, may precipitate this material, cementing and binding the subsoil into impervious hardpan. It is impenetrable to plant roots and limits the depths of the root zone. Movement of the soil waters is arrested, drainage retarded and the power to retain or deliver water is decreased. It often forms shallow basins of water saturated soil fatal to plant life.

TILLAGE In order to be successful this requires that the soil be turned over when it is in a satisfactory condition, crumbly and not so wet as to become pasty and harden into clods, nor so dry that it will not pulverize before plow. The main object is to loosen up the soil and admit air and water vapor.

COMMON PLOWING Plowing as commonly practiced simply turns over the same thin top layer of the soil year after year. Many farmers do not stir the soil more than 3 or 4 inches deep and then growl about drought and poor crops. Some work the land to a depth of 6 to 10 inches and find that it requires heavy teams or costly machinery. A few who have the capital go to the expense of using subsoiling machinery and stir the land to a depth of 18 inches. Most of them would go deeper if they knew some way that did not require such heavy outlays in money and time, for they know that our most important plants send their roots down not to 6 to 10 inches but from 6 to 10 feet or more. The use of explosives alone solves this problem. Hardpan seriously interferes with the upward movement of capillary waters and the downward penetration of the roots, and explosives alone can reach these lower strata of the soil which lie too deep to be attacked by any agricultural implements. They are the simplest means of loosening the soil to that depth so that air, moisture, and roots may easily penetrate the hardpan, creating the conditions most favorable for the rapid growth of trees and plants. When the hardpan is broken up the water capacity is increased, air is let in which corrodes the minerals, forms carbonic acid with the humus and makes many chemical and physical changes that increase the soil's fertility.

ALL SOILS BENEFITED The use of explosives is not simply a benefit in cases of hardpan, but is beneficial to all soils, and is necessary in any heavy, impervious soil. Its effect is to loosen, drain and aerate, and give additional feeding ground for the roots. It loosens up the structure of the deep material without bringing the subsoil to the surface. It fines the soil and increases the ease of root penetration. It establishes the best conditions for the storage of water, the rate and depth of percolation, increases the water capacity, and furnishes the growing plant with the right kind of water. It restores the so-called wornout soils to fertility and makes otherwise worthless acres produce record-breaking crops. The gases produced are mainly carbon dioxide, and compounds of oxygen, hydrogen and and nitrogen, none of them injurious to plant growth, and most of them actually beneficial. Explosives destroy many forms of animal life, and some fungi and other undesirable forms,of growth.

USING EXPLOSIVES Directions for loading and firing explosives may be obtained from any manufacturer and should be carefully studied. A few general points on their use may be noted. The depth at which the explosive is placed should be governed by the nature of the soil. Where the hardpan is thin place the charges below the hardpan and not closer than 4 or 6 feet apart. Where there is a thick hardpan place the charges in the hardpan and from 6 to 20 feet apart. Use a blunt bar that is larger than the cartridge to form the holes. It may be well to try out on a sample plot, varying the distance, depth of holes, and size of charges, where the acreage is large. In dry ground, if deep, the holes may be as close together as 3 feet. Light soils can be blasted to best advantage when they are wet. Heavy soils, clay and hardpan are best blasted when they are dry, as they are shattered then and not packed. The best time in the year in general is at the close of the rainy season, so as to aerate the soil thoroughly before it is wet again.

IN THE ORCHARD Success or failure date often from the day when the orchard is planted. Mistakes made then count ever afterward. The root system is fixed at that time once for all. The holes may seem deep and the furrows may be plowed deep; yet how shallow both are when compared with soils that have been blasted! The thorough preparation of the land is of the utmost importance in planting orchards and small fruit. Men are often in such a hurry to plant that they set out trees on ground unfitted by lack of tillage for their reception. Trees to do their best need to have the land in a high state of cultivation. The insect and disease resisting tree is simply one healthy and vigorous enough to resist their attacks. The ground must be so prepared that the growing trees may have plenty of room for its roots to extend into. They should go down as well as spreading out sidewise. If the roots are crumpled and confined the tree is dwarfed. The holes commonly dug for trees may seem large, but they too often have hard walls and impervious bottoms. One might as well plant the tree in a tub of the same size as such holes. Trees often send their roots down twenty feet or more; compare this with the depth of ordinary plowing. If hardpan or rock is met by the roots they are forced to spread out laterally and become crowded and matted, or spread until they interfere with their neighbors and all are injured. This crowding of the roots means the dwarfing or stunting of the tree, less vigor to resist disease, and inability to stand a dry spell. Where trees are set shallow the roots are too close to the surface and suffer during a hot spell. The more porous and looser the soil the more rapid the growth of the tree, the deeper its root system, and the quicker it comes into bearing. By blasting compact soils are made porous and converted into a sponge absorbing water and storing it for the use of the tree roots in the dry spell. As soon as the roots reach the deep loose soil that is permanently moist irrigation water is saved. Fire a charge of explosive deep down wherever a tree is to be planted. A shallow soil underlaid by a waterproof subsoil is worth little for in the rainy season the tree roots are drowned or rotted, and in the dry season the soil does not retain moisture and trees and fruits die rapidly.

All fruit and ornamental trees should have the ground prepared first by blasting; then dig a hole and fill in alternately with soil and manure, or such patent plant foods as your fancy desires and your pocketbook permits. Where the orchard is growing, deep plowing by machinery cannot be done, but trees may be kept thrifty by small shots between the rows. Where the trees are quite old start 6 or 8 feet away from the trees and put down the hole at an angle of 45 degrees to a considerable depth and use a moderate charge according to the nature of the soil. The result will be seen in the second and third crop. It is good practice to use a small amount of explosives between the rows of trees every year or so. Never replant without blasting the ground.

STUMPS Every farmer knows that time is wasted when he has to plow around stumps, dead trees, and boulders. He knows also that they prevent the proper cultivation and rotation of crops, and that seeding and harvesting machinery cannot be used around stumps. These things are bad enough, but what is worse is the fact that the **stumps are thieves,** robbing the farmer of ground that is needed, and that should be raising valuable crops. It is difficult to calculate in dollars and cents the gain in land where the stumps have been removed. That it is large is evident if one stops to think that an average stump wastes ground that would support a profitable fruit tree, or half a dozen ears of corn.

Farmers noticed long ago that crops sown where stumps had been blasted were heavy and healthy, while those on adjoining ground were dried up and sickly. This is of course due to the stirring up of the soil to depth as already explained. It is bad economy to burn stumps, as it wastes time watching the fires, and it is impossible to burn deep below the surface. **Burning** also **destroys humus** and the **fertility** of the soil, undoing the work of Nature in mellowing the earth. It is almost impossible to burn a green stump, or to remove the roots of any stump by burning so that they will not interfere with the cultivation of the ground. Digging out stumps is not only hard work, slow work and expensive work, but it leaves a great hole that has to be filled up and roots that are ever a nuisance. Pulling stumps is hard work, leaves holes to be filled, and a hard-packed soil to be plowed. If the stumps are pulled by machinery it requires too much time and power and too heavy an investment that rapidly depreciates in value. **Why chop, dig, burn, or pull stumps when there is a quicker, better and cheaper way?** One that requires little capital, few and simple tools, and no expert experience. Stumps can be removed by explosives at a fraction of the cost of pulling, and the stump is at the same time split up into fragments, the roots are broken up and the ground below and around is loosened, mellowed and invigorated. There is not only a saving of time and money, but an actual benefit to the soil, for it is better than if the land had been fertilized in the usual way.

THE TOOLS are few and simple. A two-inch auger, or a crowbar, for making the holes, which should be a little larger than the cartridge or "stick" of explosive used. A **wooden** tamping rod for tamping the hole after the charge has been placed in it.

THE EXPLOSIVE A low-grade explosive is best in clay, hardpan and compact soil, and a higher grade for sand and light soils. The caps or detonators should be high-grade, as XXXXX (5X) caps give a better result than a lower grade, for **the stronger the cap the stronger the explosion**; or, as the experts say, the greater the **initial impulse** the greater the disruptive power of the explosive.

PLACING THE CHARGE The charge should be placed so as to hit the toughest part of the stump the hardest blow from below; that is, the charge should be placed under the center of greatest resistance, which is not necessarily the center of the stump. Do not be afraid of a little extra work in placing the charge to the best advantage. The uphill side of the stump may be the meanest from which to make the hole, but is often the best If the stump is hollow or rotten a charge should be placed under each large root. All holes should be deep enough to remove the roots as well as body of the stump, and are best driven in at an angle of 35 to 50 degrees. If the stump is not too large a single cartridge properly placed and carefully tamped will take it out. If the stump is large, tunnel or trench under the bottom and make a hole as near the center as possible and only large enough to receive the cartridge, disturbing the natural earth as little as possible. Place the explosive near the wood. If the stump has a tap or peg root place the charge well down and close to this root. Tamp the hole with clay or wet earth. Properly done, the stump is thrown completely out of the ground and split, and the roots are freed from soil.

In felling trees put the charge well under them so as to lift them up. Blast when the ground is wet and get the best results. The factors to be studied are the diameters of the stumps; whether the soil is wet or dry, light or heavy; the kind of wood, age and condition of the stump; and nature and position of the roots.

BOULDERS Boulders, like stumps, are land thieves. Scattered over the ground, they occupy soil that should be in crops. They have to be plowed around and interfere with the operation of cultivating and harvesting machinery. The oldest method was to dig a deep hole and bury them, covering up, but not removing the evil. This slow, tedious and expensive method of only partially removing the evil is now almost obsolete. Prying or lifting out the boulders requires heavy machinery and capital. The cheapest, quickest and best way is to blast them out, for this not only completely removes them and permits something to be raised on the ground they occupied, but it also puts the packed soil into excellent condition, something that is not done by any other method. Do not try to remove them by "mudcapping" or "bulldozing;" that is, by placing the cartridge on the boulder and covering it with mud. This is the lazy man's way and is wasteful, expensive and dangerous, and requires a high-grade, dangerous explosive. It is true that a high-grade nitroglycerine exploplosive will shatter rocks in this way; but high explosives of that kind are expensive, sensitive, dangerous to handle or have around, and not safe except in the hands of professionals. They are not the kind adapted to the general use of the farmer. What he wants is an explosive that is not expensive, that is not sensitive under ordinary rough-and-tumble handling of careless laborers, and that is efficient and will do its work. A hole drilled into the rock near the center will with a small charge shatter the boulder completely. It is cheaper to drill such holes than to waste powder on bulldozing. With small boulders the charge may be placed as nearly as possible under the center, lifting and shattering it, and stirring up the soil. See that the charge is well tamped with mud or damp clay.

DRAINAGE Gravitational water should be removed from the area of the growing roots in all kinds of soil. Where there is an excess of water in the soil, drawing it off gives greater depth to the working soil, warms the soil, admits air, increases the amount of plant food available, lengthens the growing season, improves the soil texture, increases the voids or porosity, and prevents waste through heavy washing. Using explosives is often the quickest and cheapest way of draining overwet soils. Water standing on the surface not only damages the crops, or prevents their being planted at all, but prevents the farmer from cultivating the ground. This condition is generally due to hardpan, clay or other impervious strata. The explosives **punch holes** through these, **letting the water drain down** into porous strata **below** and restoring the soil to fertility. Many extensive swamps are caused by such impervious strata and may be drained in the same way. In such cases the advantage of using a waterproof explosive is obvious. Underdrainage removes water from all the voids except the capillary spaces and leaves the other voids free to air circulation. Underdrainage loosens, deepens and aerates the soil permanently. Explosives enable many to drain low and nearly level lands that are impossible to drain by ditches. Bore or drive holes through the subsoil or hardpan and explode rather large charges of low, waterproof explosives, so as to thoroughly loosen up the ground. This method not only secures more fertile land, but incidentally removes many an eyesore, and it maybe gets one rid of mosquitoes and other pests.

DIGGING DITCHES The quickest way to dig a ditch, no matter what the kind of soil, is to use explosives. The dirt is nearly all thrown out and scattered over the land, if desired, leaving no ridges or heaped-up stuff along the sides. Wet ground offers considerable resistance and should be blasted with a low grade of explosive. Dry ground offers little resistance to the expanding gases and a quicker explosive may be used. Where the ditches are wide use two or three rows of cartridges placed alternately.

GOOD ROADS The day of bad roads is nearly over, and no one appreciates more than the farmer the economy, advantages and necessity for good roads. By using explosives in building roads the ground is quickly drained, rocks and stumps removed, and the soil loosened for grading and shaping, and the ditches dug.

FOUNDATIONS When building a house the foundations should rest on solid ground. Blasting down to solid support is the quickest and most economical way.

CELLARS Loosening the dirt with explosives quickly prepares the ground for scrapers and shovels.

IN GENERAL There is scarcely an end to the uses to which explosives may be used on a farm. It will remove OLD BUILDINGS, dig WELLS, make DRAINS, dig POST HOLES and CESSPOOLS, split LOGS, and do many other kinds of work with economy and rapidity. It is useful in PREPARING LAND for cultivation by breaking up hardpan, shale, rock and clays on or below the surface. It REVIVES LAND, restoring the poisoned, sick soils to new fertility. Its use in nearly all soils is REVIGORATING, REVIVING, CLEANSING, HELPFUL.

ALL CROPS ARE BENEFITED It is a mistake to think that the use of explosives is limited to the orchard, or to removing stumps or boulders. The use of explosives is really DEEP PLOWING and is beneficial to all except the most shallow rooted of crops. Actual tests have proven that by their use CORN crops have increased one-third or more; and that even such crops as LIMA BEANS, tomatoes, watermelons, roses, etc., have shown remarkable growth and vigor where the soil has been plowed deeply this way.

WHEN TO DO IT Explosives may be used to advantage at any time. "Do it now" is a good time to begin. Where an explosive is to be used on a large scale a good time is immediately after harvest before the cold weather sets in. Then the waters of the rainy season will be absorbed and stored for use during the coming hot, dry season.

EXPLOSIVES Everyone using explosives to any extent should study at least one of the many books that explain their manufacture and nature. In the general sense, an explosive is a substance that is capable under certain conditions of a sudden and considerable increase in volume, such as the sudden conversion of a solid or liquid into gases. Gunpowder, a mixture of carbon, sulphur and nitre, is converted instantly into gases by contact with flame. Water in the form of confined steam expands with explosive violence when the pressure is released. Flour dust mixed with air forms gases so rapidly when ignited that the effect is that of an explosive. Gas jets leak and the gas mixes with the air and the room becomes filled with an explosive mixture that only needs a match to make it dangerous. The materials combine chemically and the heat from this chemical action expands the gases formed with such rapidity as to be disruptive in effect. The chemical reactions in some materials can be started by bringing the different chemicals into intimate and minute contact by a blow or by compression, as when gunpowder is struck or compressed, or when slight friction is applied to a drop of nitroglycerine, or a fulminate is tickled lightly with a feather. Other compounds cannot be exploded by a shock or blow, but are sensitive to heat or flame. A few cannot be exploded by shock or flame, but the chemical action is started by special means, such as fulminating caps, chemical preparations, or even high vibrations like the X-ray. Technically explosives are classified as HIGH EXPLOSIVES or as LOW EXPLOSIVES. In high explosives the chemical reaction once started takes place throughout the mass in practically the same minute fraction of time, and the result is most violent, producing a terrific crushing or shattering effect. In low explosives the chemical reaction is relatively slow and produces more of a pushing or propelling effect. While this difference in time exists, it is not appreciated or its effect realized by the untrained mind any more than the speed of photo camera shutters that move in from the 1000 part of a second to the 100,000 part are appreciated by the amateur. Explosives are now made from all kinds of material and for all kinds of work. The BEST EXPLOSIVE is one made especially for the kind of work to be done. High explosives are necessary in many kinds of work, but not, for example, in firing a cannon where the shell has to be pushed out with startling rapidity without bursting the cannon. The agriculturalist should use only explosives especially prepared for his work. He does not need the high explosives, or those that are sensitive to shock, friction or that are exploded by flame. He does not need to use dangerous and unstable compounds that have to be kept frozen in order to be handled safely, and then run the risks attending thawing out before they can be used. What he should do is to use an explosive that stands all ordinary shocks of handling and transportation, that does not explode, but simply burns up when set on fire, that does not freeze or have to be thawed out, that is waterproof and not subject to deterioration by action of the weather. He does not need and should not use the expensive, high-grade nitroglycerine explosives. The various grades of low explosives that cost less without losing quality will do all his work, from stumps and boulders to deep plowing, better than high explosives.

DANGER IN THE CAPS

The principal danger in the use of explosives on the farm comes from the "cap" or fulminate used to explode the stick of explosive. This danger is avoided by careful use and is not prohibitive. The caps should only be used and handled by a careful and thoughtful person. Absence of mind may cause a sudden absence of some useful portion of the body, as a single cap can blow off fingers or shatter one's hand. These copper caps are partially filled with a white substance that is largely fulminate of mercury, which is sensitive to even slight taps or blows. A cap should **never be tapped** to get the sawdust out of it. No toothpick or stick should be used to clean it out. In fact, **nothing should be allowed to touch the fulminate** in the cap. The fuse should be cut off square and never at an angle, for the point in this case may get pushed into contact with the fulminate and disaster result. The square end of the fuse should be inserted into the end of the cap to permit the cap to be crimped on to the fuse with pliers made for this purpose. Discharge any man instantly who bites the cap on to the fuse. Let him be buried from some other farm than yours. Insert the cap with the fuse crimped on into the cartridge, and **tie the top of the cartridge firmly to the fuse.** This is to prevent the cap from being jammed down into the cartridge, or being pulled out of contact with the explosive while loading the hole. Pulling the cap out of contact with the powder while straightening the fuse **is a common cause of misfire.**

Nothing is a safety or safe explosive when in the hands of a careless or ignorant person, and the reckless, foolhardy person who is fond of showing off is worse than anyone else. A dunce has to get on the best he can with what little brains he can utilize, but a fool is reckless when he knows better. Eliminate these two and anyone of average intelligence can use with safety the explosives made especially for use on the farm.

An explosive is simply **enormous energy in small compass,** but steam, gasoline, electricity, matches, coal oil and all forms of machinery are only energetic forces **bottled up and harnessed** by experts ready to obey and be the willing servants of man if he will use them right and not abuse them.

POINTERS All manufacturers of explosives issue circulars giving directions for using their products. but there are a few general points everyone should know. The fuse, as already stated, should be cut square across and the fresh end put into the top of the cap. but never pushed down to the fulminate. Spread grease or tallow over the fuse at the junction with the cap when firing wet holes. The stronger the cap the stronger the initial impulse and the stronger the explosion with any and all explosives.

Some explosives are made to be exploded **only** by No. 5 or 6X caps and cannot be completely exploded with anything less. Do not use cheap fuse or cheap caps. Use electrical firing machines if possible, especially if there are a number of holes to be fired at the same time. Never store the caps in the same place as the explosives. Tamping is important with low explosives. Ram in with a **wooden bar,** never using iron on account of the cap. Use clay or compact dirt and then wet it, or use mud that will pack well. Loose dirt, gravel, sand, stones, etc., are of little service, as the object is not to weigh the explosive down, but to **close all vents** so as to hold in the gases. All explosives do their best work when **closely confined** in the center of the material to be broken or thrown out. Never use an explosive that is frozen. Never use a nitroglycerine explosive that has once been wet and then dried out. In placing the charge remember that the effect of the shot is affected by (1) the shape and size of the stump, rock or soil, (2) the texture of the material, whether it is hard and firm or soft, loose, brittle or tough, (3) the structure of the material, whether it is laminated, stratified, fissured, massive or fragmental, (4) and, finally, its elasticity or ability to give or stretch.

VERTICAL FARMING

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PROF. OF GEOLOGY

UNIVERSITY OF SOUTHERN CALIFORNIA

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VERTICAL FARMING

PART I

The Origin and Character of Soils

Soils Are Rock Waste.—Soils were not originally a part of the earth's surface, but have been formed slowly by the crumbling and breaking up of the surface rocks into fine particles, such as clay and sand. Sometimes this breaking up occurred where the soils are now found, and the character of the soil is governed by the kind of rock that was left on the surface, while in other cases the rocks and the soil that came from them have been carried thousands of miles and mixed with other material, forming a conglomerate mixture from many sources. The highland and mountain soils in this country have, as a rule, been formed very near the places where they are now found, while the soils in the larger valleys, and along most of the coast line, have resulted from material washed down from the hills and deposited along the level stretches near the sea. Much of the soil of the more northern states has been brought down from Canada by the movement of ice along the surface.

This breaking down of the rocks and formation and moving of the soil has taken a long time; but this work is yet going on, and the exposed rocks, boulders and ledges in our fields and mountains are yearly being attacked by the different forces, and are slowly yielding up material to help replenish the older soil. Different natural and artificial processes are also going on in the soils that may either improve or injure them. Most of these processes can be controlled by man and made to be his servant, so that he can become a great factor in the formation of profitable soil.

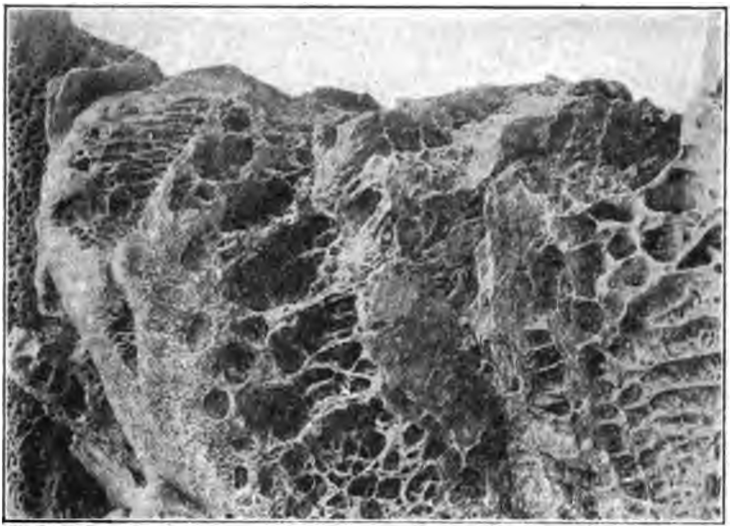
The breaking down of the original rocks has been accomplished by very simple means, the action of which has been very powerful.

Work of the Atmosphere.—Everyone knows how a piece of iron is attacked and falls into a powdery iron dust, which is nothing but iron combined with oxygen taken from the air to form a different substance called iron oxide. The oxygen, carbon dioxide and other gases of the air attack the iron, lime and other elements in the rocks, forming new substances and causing the particles to fall apart, as is the case of the iron rusting. Rocks are also carved, eroded and worn away by the cutting and sawing action of the wind, especially when it carries with it any considerable amount of dust or sharp sand particles. In this way large rocks are sometimes entirely worn away. In some localities in this country the sand is swept across the level

U. S. G.S.

EFFECT OF WIND ACTION ON ROCKS

stretches so severely as to smooth off the rough places on brick walls, and to scar the glass in windows.



U. S. G. S.

LIME STONE AFTER EROSION

The Part Played by Water.—Much rock material is slowly dissolved out and carried away by rain water. This is usually carried long distances before being thrown back into a solid state by the evaporation of the water, or by coming into contact with some other substance that causes it to be precipitated. Often this reforms into another rock that may be harder than the original one.

A much greater effect of water, however, is in the formation of ice, which expands and acts as a powerful wedge in splitting off small fragments. You will often notice along the foot of a cliff, or at the base of a large rock, a mass of small splinters of stone that have been pried off the parent rock in this way. Running water also slowly wears away even the hardest rocks, reducing their close material into finer particles.

ENTRANCE TO THE GARDEN OF THE GODS
A BEAUTIFUL EXAMPLE OF EROSION

RUNNING WATER SLOWLY WEARING AWAY HARD ROCK

Glaciation.—During the glacial age vast sheets of ice, carrying with them boulders and everything else that was movable, passed over much of the United States and Canada, and ground up the rocks into soil. Large areas of the richest soils were formed in this way. Smaller movements of ice occurred in the valleys of the Northwest and resulted in the formation of some wonderful soil areas there. These movements of ice leveled down the rough surfaces of mountain ranges and scoured out wide valleys.

BOULDERS WORN SMOOTH BY GLACIAL ACTION

Variations of Heat and Cold.—The variations of temperature from day to night and from summer to winter have also been busy in grinding out soil meal. When it is warm the rocks expand slowly, and contract under lower temperatures. The different minerals in the rocks expand and contract unequally, causing cracking which flakes off the outside of the rock and permits of its being attacked much more easily by other agents of destruction, or perhaps, better said, of creation. The effect of these changes of temperature are more noticed in some of the higher and drier regions where the hot evening gives way quickly to cold night. It has been reported that this action is at times so violent as to split large pebbles in half so quickly that a noticeable report, like the bursting of a percussion cap, is made.

ROOTS OF TREE WIDENING A CRACK IN A ROCK. WHEN GIVEN FISSURES TO GROW THROUGH ROOTS WILL PENETRATE HARD MATERIAL TO GREAT DEPTHS

Plants Render Assistance.—Just as soon as a little powder is formed from the rocks by the action of these agencies, minute plants, some of which can be seen only by means of a microscope, fasten on the rock meal and begin to grow. As they mature and die, their tiny bodies add the first organic matter to the newly formed soil and help prepare it for larger and more vigorous plants. The study of this action is very interesting, and a short search into any stony place will reveal many examples. Mats of short moss will be found growing on what seem absolutely dead and impervious stone. Trees can be found sending their roots into the smallest fissures in the rocks and bursting them wider. It is a hard life for these plants, and their growth is slow and stunted, but it is one of their missions in nature and they go on with the heavy work, giving to man at the same time a wonderful revelation of what he can accomplish in the way of improvement by giving cultivated trees and smaller plants a suitable place to grow, rather than force them to combat all the adversities of a resistant soil.

Animals Help.—Tiny worms and bugs soon begin to burrow into the weaker points of the rocks, and as the work goes on much larger cousins follow them. Their action is to open channels through which water can reach more effectively the harder rock within. They also do large amounts of grinding and mixing on their own part. Their excretions and their dead bodies add more organic matter to the soil and help pave the way for a good garden or a fruitful field.

U.S.G.S.

SOIL GROUND AND MIXED BY ANTS

Each Force Helps the Others.—These forces in their slow work of grinding up the rocks into earth meal do not work separately, but each helps the other. When one worker has opened a way into the rock, his success is immediately followed by activities on the part of the others. The roots and worms open channels to permit the entrance of more water, which may mean more freezing and more cracking, and there is more room for roots. An expansion crack works the same way. The pits made in the face of the rock by the action of the air make suitable homes for the mosses and other plants. It is a big job, and the work is accomplished only by all hands keeping busy.

The Formation of Humus.—The rock powder or meal does not of itself make a desirable soil, and other matter must be added. Microscopic plants must flourish to help in the work of crop production; water must be present, and as a rule, the more humus the better the crops. This humus is not a strange sort of stuff at all, as it is only rotten trash from dead plants or animals. Mention has already been made of how its first start is made. This is later augmented by the growth of larger plants which have more leaves, twigs and roots to rot. In increasing the amount of humus in a soil the work of man, when intelligently applied, can be made to do wonders.

GREEN MANURE CROP FOR INCREASING HUMUS

How Soils are Moved.—After the agencies just described have ground out the rock powder, nature keeps right on at work in moving and sorting out the soil particles. This work is done by the action of:

Gravity.—The soils formed on the mountains and cliffs fall to the base forming a heap of debris which is called " tallus." Where the slope is steep, this falling is immediate; but where the land is more level, the movement is slower and is more of a slide than a fall. Gravity is ever at work moving soils from high to low levels.

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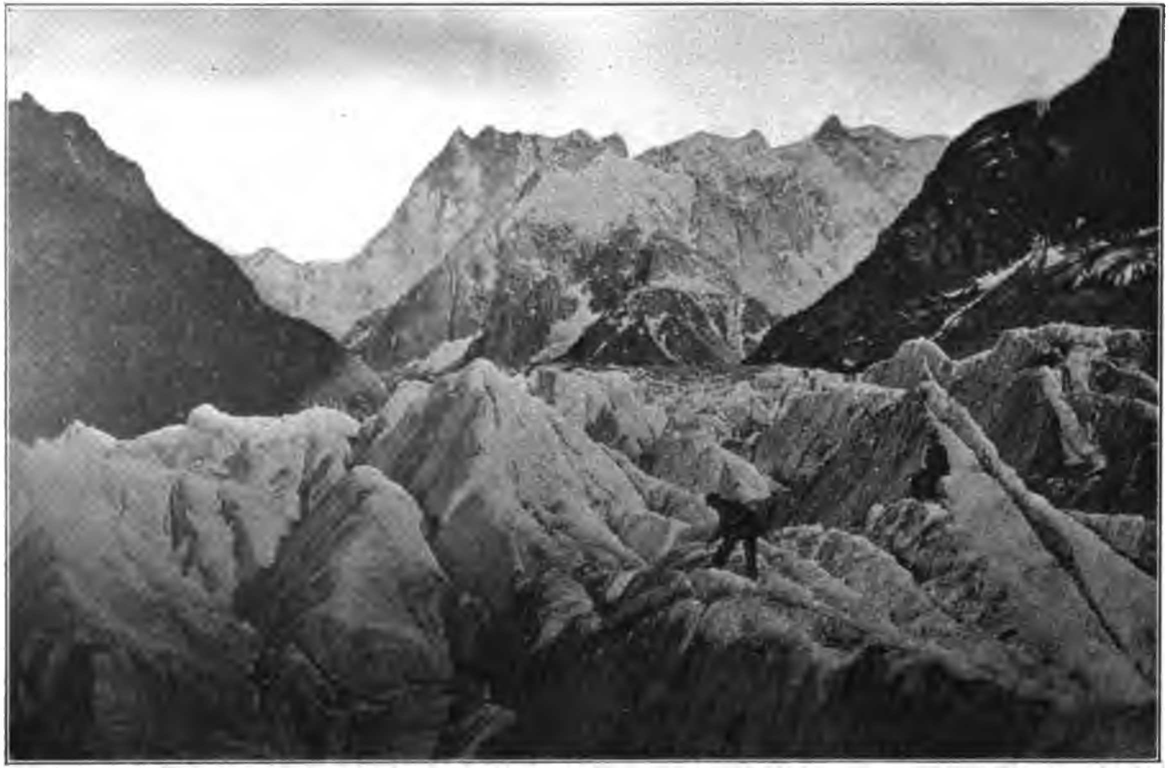
THE MOVEMENT OF SOIL FORMING MATERIAL BY GRAVITY.

Water.—Every drop of water that falls on the earth can move a particle of soil at least a little distance. These drops of rain run together to form rivulets, each with its little load of soil. Rivulets meet to form streams, and these join to form creeks, and the creeks unite to form rivers. A creek or river in flood-time is a stream of soil moving down from the factory to be spread out over distant valleys and plains, or to fill up the bottom of the sea so that it can finally be used by man to grow food and raiment.

Glaciers.—The great sheets of ice that have already been described moved great distances, and carried with them large amounts of soil and soil material. Some of them moved from Canada into what is now the United States, and brought fertile material far within our borders to make some of the richest land in the world.

Winds.—The housekeeper knows how fast dust accumulates over everything, and how it thickens on furniture and carpets if left undisturbed for even a short time. The winds

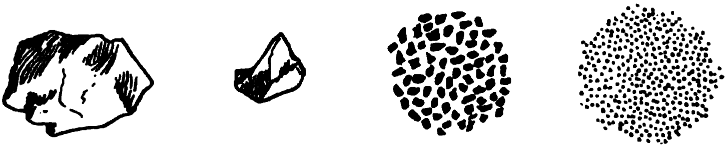


AN ALPINE GLACIER GRINDING " SOIL MEAL " AND MOVING IT FAR FROM ITS PARENT ROCK have been busy, not for days but for centuries untold, picking up soils in one place and dropping them in another—sorting and arranging them until it is probable that any given section of land anywhere contains particles contributed by every other section in that district.

Residual Soils.—Not all soils are moved in these ways. In places, sometimes large, sometimes small, the original rocks of the locality have weathered down into soils that remain just where they were formed. These are known as " residual soils," and embrace a great variety, some of which are fertile, while others are not so well favored. The proportion of residual soils to transported soils varies greatly in the different parts of the world.

Some of the Physical Characteristics of Soils.—Soils have a number of marked physical characteristics, some of which are of interest only to the exact scientist, but many of these characteristics are of the greatest interest to the poorest farmer. The greatest advances made in the Science of the New Agriculture have been due to the study of these physical characteristics of soils, and the application of the discoveries along this line have tended toward a better and more profitable agriculture.

Soil Texture.—One of the most noticeable differences in soils is the variations in the size of the grains of rock powder of which they are made. The fineness of a soil is spoken of as its " texture."[1] The sizes of grains most discussed and best understood both by the student and farmer are: clay, silt, sand, and gravel. It is well known that sand, loam, and clay soils will not raise the same crops equally well. There are good reasons for this. In a sandy soil the particles are relatively large and do not pack so closely together. No matter how tightly packed a soil may be, there are always small openings and cavities between the particles. These are called " pores." The sandy soils do not pack so closely together as do the clays, and the pores are therefore larger and permit a much easier movement of water and air in the soil. The clay soils pack more closely together and reduce the size of the pores so that both the water and air move more slowly. The silts and loams are intermediate between the sands and the clays. Loam soils are made up of mixtures of fine and coarse soil particles. If the loam carries a large percentage of sand it is known as a sandy loam; if the clay particles predominate in amount, it is known as a clay loam. The presence of gravel among the other particles materially affects the texture of a soil and often the fertility as well. When a considerable amount of these particles are present in a loam soil it is usually called a gravelly loam, the difference in clay and sand being maintained as before. The intermediate textures, such as fine sandy loam, silt loam, and the lighter clay loams are usually considered the best, as they tend to be light, well drained and easily cultivated.



COMPARATIVE SIZES OF SAND AND CLAY PARTICLES (ENLARGED)

When the percentage of fine gravel and coarse sand is high, the soil is likely to be too loose, too easily drained, and not likely to withstand drought well. Such a soil, especially in the rainy regions, is likely to be deficient in one or more of the chemical elements needed for the production of plants. Where the percentage of fine silt and clay is high, the soil is likely to be cold, heavy, and sour. Such a soil, unless well tilled to considerable depths, resists the ready movement of air and moisture.

Soil Structure.—Another important physical characteristic of soils is the way the particles arrange themselves as they lie in the field. A coarse sand is found to have every particle lying separate, and alone with no attachment to the particles which it touches, unless they are cemented together by excesses of lime or similar substances. The clay in a path will be found to have its particles arranged in much the same way as the sand, with the important exception that each is pressed close to its neighbor and bound there by cohesion, by adhesion, by some other substance present, by interlocking corners of the particles, or by other means. When such a soil is disturbed it does not fall apart like sand, but remains in close, hard lumps or clods. In these soils we have the extremes of structure—the open structure, or the individual grain and the dense structure or arrangement of the pubbled soil. A well-tilled plat of clay or loam will be found to have an entirely different structure. Here the fine particles of clay, silt and sand are bound together in little groups or crumbs. These crumbs or granules can be easily detected by picking up a handful of the soil and gently breaking it apart. These crumbs lie close against other crumbs, but unless poorly handled in cultivating they do not become sealed together. This is the ideal structure of a soil, and it is toward the formation of such granules that we should direct our attention, especially in the heavier soils. When such a soil is cultivated wet, the pressing action of the plow or harrow tends to force the particles closer together and to form the undesired puddled structure; but if the moisture content is just right, the same plowing will tend to make the granulation still better. Additions of humus material, and, on some soils, of lime, help also.

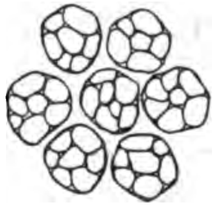
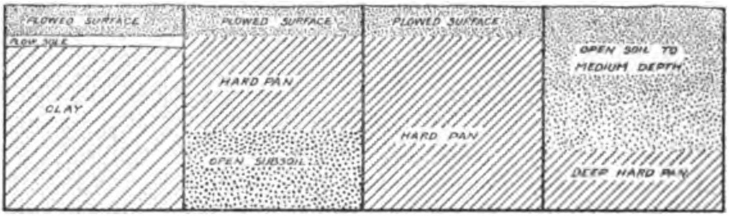


DIAGRAM OF SOIL GRANULES

Such a crumb structure in a soil brings about most of the benefits and advantages of both a sand and a clay. It drains well, and because of its open structure warms up well in the spring. The openness permits easy and good plowing. The fine particles absorb and hold the large amount of water needed for the crop, and if properly cultivated to preserve this moisture, will tide heavy crops over longer periods of rainless times. Another great advantage of the crumb or open structure of clay and loam soils is that they allow the roots to grow quickly to great depths. This affords the plant a much larger amount of soil from which to draw moisture and food, and consequently yields heavier crops. In another paper the good effects of this open structure on beneficial bacteria will be pointed out.

Hardpan and Plow Soil.—Another soil structure that needs attention is hardpan. Sometimes this is simply the tight puddled clay that has already been described; and sometimes it is clay, silt or sand that has been cemented together by some chemical or mineral substance in the soil, or by the soil particles themselves being so tightly pressed together that they prevent the movement of water and air, and retard the growth of roots. One kind of hardpan is called plow sole, and is found just at the bottom of the plowed furrow where the slide of the plow has been for years packing down the soil just where it needs to be opened. The relief from such conditions is found in deep cultivation that will crack the material to pieces and permit good drainage where it is bad. This breaking must, of course, be deep enough to reach the seat of the trouble. Any adverse conditions, such as an excess of alkali or a lack of lime, should be immediately corrected.



COMMON TYPES OF HARDPAN

Soils and Subsoils.—By soil we mean the surface as contrasted with the lower stratum of subsoil. Ordinarily they have come from the same source, and at times are so much alike that it is hard to distinguish between them. This is particularly true in the semi-arid regions, and in the deep aluvial belts. Usually there is a difference in texture, structure, and color. The soil has been well weathered and has undergone changes that will permit the giving up of its mineral plant foods to the roots of plants. These changes have gone on more slowly in the stiffer subsoils, and much of the mineral substances have not been acted upon sufficiently by the air and by bacteria to give up the needed foods. Deep cultivation and the use of explosives open up these soils to the action of the air and other agencies so that these foods may be prepared for the roots, and increased fertility and greater returns in crops are the result.

Soil Areas, Series, and Names.—The soils of the United States are classified into thirteen subdivisions called "Soil Provinces," or regions, according to the essential geographic features, such as the Atlantic and Gulf Coastal Plains Province, the Appalachian Mountain and Plateau Province, the Great Plains Region, the Arid Southwest Region, and the Pacific Coast Region. The soils of a province are classified in soil series. The soils in a series have the same range of color, same general character of subsoil, a common or similar origin, about the same structure, and broadly, the same type of relief and drainage. The soil series are divided into individual soils, which generally receive local names, as: Portsmouth Sandy Loam, which is found in several states from Delaware to Mississippi; Vermont Silt Loam, of Kansas and Texas; and the San Joaquin Fine Sandy Loam, of the Pacific Region. A soil class includes all the soils having the same texture, and are called: sands, loams, clays, fine sandy loams, clay loams, clay loam adobe, or such other combination of descriptive words as best fits the peculiarity of the soil.

Maps of the soil surveys of the various provinces, and descriptions of the series and individual soils of the surveyed areas will be found in the annual reports of the U. S. Bureau of Soils, and may be consulted at the larger public libraries; or if a particular county has been mapped, the report on it can be gotten from the U. S. Department of Agriculture.

Chemistry of the Soil.—While it is true that the productiveness of a soil depends more on its physical character and condition than upon its chemical composition, yet the chemical elements are of great importance and must be taken into consideration. Many chemical elements are needed for the production of a plant, but it is seldom, with the exception of potash, lime, phosphorus, or nitrogen, that any of these is not present in sufficient amounts. All of these except the last named occur in many rocks, and are therefore found in the soils in varying amounts. When, on a particular soil, one or more of these is absent or deficient, it is necessary to add it in some form of fertilizer or manure.

The soil particles may not be weathered enough to make these minerals available, or there may be little in the surface soil and more in the subsoil. In either case the soil is improved and the plant food brought within the reach of the crop by breaking and stirring up the land with explosives.

Fertilization and Chemical Correction.—In addition to the proper physical condition, it is necessary to have the chemical condition of a soil well regulated in order that we may get the proper returns from our labor. Some foods may need to be added to the soil, or it may be essential that a harmful substance be removed or neutralized. This work will be considered in a following chapter.

QUESTIONS

1. Describe the formation of one type of soil not made from rock particles.

2. Does the action of the air always soften freshly exposed rocks?

3. Name the forces that have been most effective in forming the soils in your vicinity.

4. By what agencies have your soils been moved?

5. Is the typical soil of your farm finer or coarser than the underlying subsoil?

6. Can a mixture of coarse sand and clay become as tightly compacted as a dense clay?

7. What, in detail, are the processes in the formation of plow sole on your typical soils?

8. Why are arid soils less troubled with shortages of plant food than humid soils?

9. What physical characteristic of your soils lends itself most readily to improvement?

THE RESULT OF GOOD DRAINAGE, GOOD AERATION AND PLENTY OF PLANT FOOD

VERTICAL FARMING

PART II

Fertilizers and the Chemical Properties of the Soil

HOW PLANTS FEED

The fertility of a soil is its ability to produce crops. It is not one condition, or two or three conditions, but the sum of all conditions. It does not consist simply in hauling manures or buying chemicals. It means that the water, air, temperature, soil bacteria, tilth, and plant food or soil solution exist in the right conditions and proper balance as well as in proper amount. It is possible for seed to sprout, the crop to grow and ripen, and the yield to be the best only when all these conditions are fulfilled. Mere richness in mineral foods avails nothing if water is lacking to maintain a large amount of soil solution for the roots to absorb. The plant food may be there but may not be soluble and cannot be absorbed. It may be soluble, but in a form distasteful to and therefore rejected by the roots.

All soils, even those considered poor, contain vast amounts of plant food that is not naturally available, but which can be converted into an available form. In such a case the problem is one of condition and not one of total content. A worn out soil is often only an unsanitary one and can be rebuilt to a high state of productivity by proper cultural methods.

Chemical Properties of the Soil.—While hundreds of minerals are known to science, only a few are used in nature in forming the common rock from which most soils are derived. The more important of these to the farmer are potash, phosphorus, and lime, as these are at times deficient or else appear to be deficient. Such elements as iron, aluminum, and silica may be ignored, as they are nearly always present in sufficient quantity to more than supply any demand made on them.

For most agricultural conditions it is almost imperative that the soil be not acid. The chief corrective for a sour condition is lime, which is usually present in sufficient amounts for a food, but in many soils is needed to overcome the sour conditions produced by vegetable decay or bad drainage. It may be added in several different forms. At present, carbonate of lime or finely ground limestone or marble dust is largely used for this purpose. This form is preferred by many on account of there being no danger of trouble from an over-application. Hydrated lime is also largely used, as is rock or quick lime. In

Courtesy Charles Warner Co.

MAMMOTH LIME KILN

using the last named form, care must be exercised to prevent a heavy application from burning the organic matter or humus out of the soil. Ground or burned sea shells are also extensively used and make an excellent form of agricultural lime. Gypsum is used under certain conditions. Lime also has a material effect on the structure of the soil, especially when it has a tendency to be sour, by causing it to granulate better, thereby increasing its power to absorb and hold water. Especially in the east and southeast the use of lime is imperative for the best success in growing alfalfa and certain other legumes. The cow pea seems to resist a sour condition in the soil remarkably well. Lime also helps somewhat to liberate potash from resistant minerals. Salt is sometimes used for the same purpose. The growth of nitrogen fixing bacteria is greatly stimulated when lime is added to make up any deficiency that may exist in the natural soil.

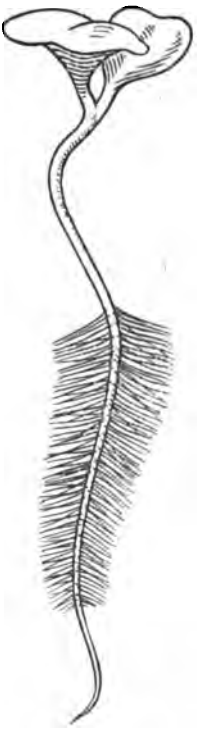
Potash is a highly essential plant food. It exists naturally in most soils and in some of them is found in large amounts. In some soils, notably coastal plains sands, it is present in but

SHIP DISCHARGING CARGO OF EXPENSIVE FERTILIZERS small amounts and must be added artificially. Considerable amounts are found in natural manures, but the great supply is imported into this country from Germany.

Phosphorus is also present in most normal soils, but the percentage is small in some of the most valuable soil provinces of the country so that it must be added artificially. Large amounts of phosphate rock are mined in this country. The rock may be ground and added to the soil in the form of a fine powder, provided the soil has a good supply of organic matter. If this organic matter is deficient and the soils are thin, the best results are reported from the use of acid phosphate which is the phosphate rock after it has been treated with sulphuric acid. Large amounts of phosphorus are used in the form of slag and bone products. The United States is more than self-sustaining in the supply of phosphates and export large amounts annually.

Another of the important elements is nitrogen, which is found in the form of nitrates in some of the desert regions. In this form it is very soluble and is washed out of the soil by rains. It is found in normal agricultural soils in varying amounts, but is often in too small quantities. Commercially it is obtained from fish and packing house scrap, from cotton seed, from nitrate of soda imported from Chili, and from the air. Nitrogen is a gas and makes up the larger part of the air, from which it may be taken in large amounts by certain bacteria growing on the roots of legumes and by other microscopic plants working alone. Further mention will be made of this later.

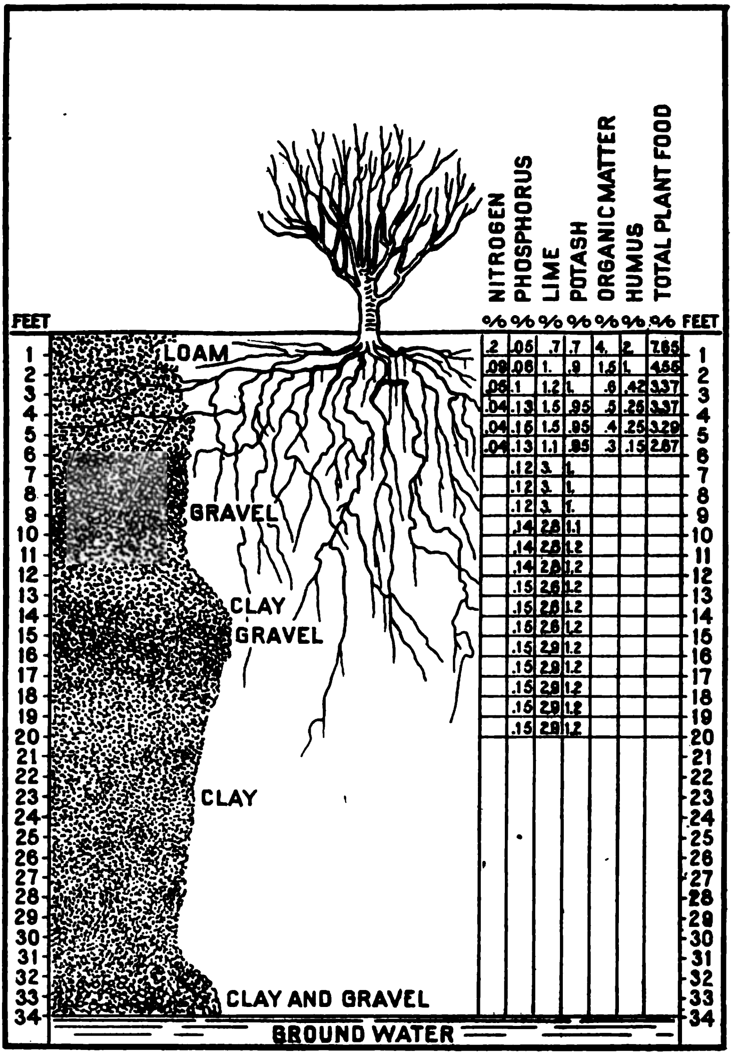
How Plants Feed.—Plants feed by absorption through the roots and by inhaling the air. When a plant is burned, most of its weight is lost in the form of gases and but a small part is left as ash. The ash contains the mineral matter which came originally from the breaking up of the soil minerals, or was added as a fertilizer. The rest, or the part that was lost in the gas is made up of carbon, hydrogen, oxygen, and nitrogen. The carbon is taken in through the leaves from the carbonic acid gas of the air. The hydrogen and the rest of the oxygen are taken in through the roots in the form of water, and the nitrogen is derived from the soil where it may have accumulated from artificial supplies, from the action of bacteria, or from the decay of organic matter. The relative amounts of these elements demanded by different plants varies considerably, as some require a large supply of one food element while others can grow well with much less of it.


ROOT HAIRS

Only the root hairs, the most delicate part of the root system, can absorb foods. These are tiny threads growing out from the roots just back of the tiny feelers or root tips that thrust themselves through the soil. The walls of these root hairs are very thin and absorb the soil solution direct as they lie in close touch with the soil particles covered with their thin coat of " Mineral Soup." These dissolved mineral foods then pass on into the circulating system of the plants as sap, and are carried up to the leaves. The sap in conjunction with the carbonic acid taken in by the leaves then forms the starch, sugar and similar compounds of the plant and the excess of water is lost through the leaves. The amount of water evaporated in this way is enormous. It has been found on experimentation that it requires from 200 to more than 600 pounds of water, passing through a plant in this way, to make one pound of dry crop. These large amounts of evaporated water show how necessary it is to keep the soil in such a condition that it will absorb the maximum amount of rainfall and hold it to supply the growing crop. It is also necessary that these tiny root hairs, that are so small that it would take 300 or more laid side by side to cover an inch in width, be able to creep and grow always deeper and further into the soil, unhindered by impacted soil, hardpan, or other obstructions.

The roots do not reach down to all of the water they use. Some of it is pumped up to them as oil rises in a lamp wick, by capillary action. This rise is much faster in well granulated soils than in hardpan or tight clay. It is evident, therefore, that no method of cultivation can reach down deep enough to overcome the difficulties of feeding roots except blasting the subsoil with explosives.

Unavailable Plant Foods.—Attention has already been called to the large amounts of mineral plant food bound up in insoluble minerals, and to the enormous amount of the highest priced plant food (nitrogen) that is present in the air but not directly available to the field crops as food. The changes that some of these must undergo in order that they can nourish the roots are chemically very complex, but, in the practice of the art of farming, can be well controlled. The nitrogen must be combined with oxygen. This change is most effectively brought about by a certain group of bacteria which grows in knots on the roots of peas, beans, clovers, alfalfa, and kindred plants. They breathe in the free nitrogen gas and combine it with other elements in such a way that large amounts are fixed and held in the soil in a combined form that is very nourishing to succeeding crops and also to the crop with which they grow. Other forms of organisms accomplish the same purpose, working without the assistance of the leguminous associates. Both forms require certain well defined conditions in which to work. Each of these is so essential that it would be hard to name the more important one. The soil must be well drained so that there is no clogging up of the soil pores with water, but at the same time the soil must be moist. The soils must also be warm, for the activities of these wonderful little farmers' aids are retarded if stopped by frost. Large supplies of air are equally essential. As most of these conditions attend a deep tilled soil, it might be said that the beneficial bacteria of the soil are all deep tillage enthusiasts. They are found at considerable depths in the porous types of soil, but cannot live much below the surface in tight clays and hardpan. They also keep busy on insoluble



NITROGEN %	PHOSPHORUS %	LIME %	POTASH %	ORGANIC MATTER %	HUMUS %	TOTAL PLANT FOOD %	FEET
.2	.05	.7	.7	4.	2.	7.65	1
.09	.06	1.	.9	1.5	1.	4.56	2
.06	.1	1.2	1.	.6	.42	3.37	3
.04	.13	1.6	.95	.5	.25	3.37	4
.04	.16	1.5	.95	.4	.25	3.29	5
.04	.13	1.1	.95	.3	.15	2.67	6
	.12	3.	1.				7
	.12	3.	1.				8
	.12	3.	1.				9
	.14	2.8	1.1				10
	.14	2.8	1.2				11
	.14	2.8	1.2				12
	.15	2.6	1.2				13
	.15	2.8	1.2				14
	.16	2.6	1.2				15
	.15	2.9	1.2				16
	.15	2.9	1.2				17
	.15	2.9	1.2				18
	.15	2.9	1.2				19
	.15	2.9	1.2				20

THE DEEPER PLANT FOOD MIGHT JUST AS WELL BE IN EUROPE FOR ALL THE ATTENTION THAT IS USUALLY GIVEN IT forms of combined nitrogen that may be added to the soil, and convert it into usable forms.

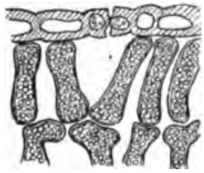
Soil changes also materially affect the availability of phosphate material. In nature it is always combined in slowly soluble compounds. In commercial fertilizers it is usually combined with lime. Different relations in the amount of lime to the phosphorus effect the solubility of the phosphorus. In badly drained land the phosphorus is often found combined with iron in little balls of "bog ore" that are very insoluble. Many other examples of combinations of plant foods could be brought out going further to show how the air, water and bacteria assist the changes. In every case the benefits brought about demand deep stirring of the soil, such as is produced by exploding small charges of slow powders in the subsoil and opening a way for the liberators of plant food. No other practical method can bring about the desired results.

Deficient Plant Food.—If the rocks from which a soil is derived are deficient in any needed food, it becomes imperative sooner or later to add some material that will make up the deficiency. The original and best general fertilizing material is manure, as it adds not only certain amounts of plant food, but also large amounts of humus. Forest mould, litter, straw, and other materials of like nature add some of the fertilizing elements and also humus. The number of materials that may be used to add plant food is great. Some materials carry but one needed element, while others carry two or three. There can be no general rule promulgated to guide in choosing fertilizers, as different soils and different crops demand certain chemicals in different forms.

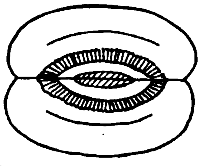
Soil Amendment or Correction.—Some soils well supplied with mineral and organic plant foods have some trouble, such as sourness or an excess of alkali. Materials not classed as foods are used in the correction of such conditions. These materials are generally known as "Soil Amendments." In the correction of black alkali, gypsum is added to change the sodium carbonate to a less harmful compound which can more readily be leached out.

The other great amendment is lime, the chief use of which has been described in the correction of sour or acid soils.

Use What You Already Have.—From the foregoing we see that there are supplies of practically all the plant foods in normal soils, and that additions of fertilizing materials, while absolutely essential in some cases, are expensive. Some of the foods already in the soil are not in the form needed by the plant, but can be changed into usable forms by properly controlled natural agencies. The agencies needed for these changes are always at their best under certain soil conditions. For the different changes the conditions are identical—a moist but well drained soil, an abundant supply of air in the soil, the presence of more or less humus, and a suitable temperature. To obtain most of these is easy, when we consider only the soil, as it can be done with a plow, but the surface is not half of the farm—we want to use several feet of depth for a good reservoir for moisture, a factory to rework and prepare the foods, and a good home for the roots. This naturally demands that the clay or hardpan be broken up. The plow cannot get down to the trouble and there is but one other agent that can do the work—a reliable low-freezing explosive.



SECTION BREATHING PORE OF A LEAF (GREATLY ENLARGED)



SURFACE VIEW OF SAME

Making Fertilizers More Effective.—Heavy applications of fertilizers to force bumper crops are attended with certain dangers. If everything goes along all right, and there is always plenty of moisture to dissolve the fertilizers and prevent the soil solution from becoming too rich, the desired results will in all probability follow. In most regions where such fertilization is practised, such constant supplies of soil moisture are not always to be relied upon. The result is that when the young plants get vigorously started on their nourishing ration and then meet a season of drouth they are " scorched " or " burned " by the too concentrated food, and are left in worse shape than if there had been no fertilization and they had been forced to draw all their food from the soil minerals.

Even where the conditions are normal rather than extreme, the increased growth caused by the fertilizer calls for a greater supply of moisture to support the enormous loss through evaporation from the leaves, and the fertilizer has in no way met the increased demand for the water. The correction for either condition is simply the prevention of excessive amounts of the water being lost by drainage and holding it stored in a deep tilled, open subsoil. A tight subsoil will not absorb and hold the moisture in this way and needs the welcome relief of a small amount of well placed explosive to shatter and open the soil, so that it can meet the demands for more water.

QUESTIONS

1. Name in full the conditions necessary for heavy yields of your money crop.
2. What fertilizing material is lacking in your soil, and in what form would you supply the deficiency?
3. Do the large brace and tap roots of plants absorb plant food from the soil? What is their duty?
4. Will a large tree draw most of its food from the ground immediately around the stump or from the soil further away?
5. What is the source of the most used chemical fertilizer in your community, and how is it prepared before being offered for sale?
6. What effect has lime on clover on your farm? On wheat? How can you prove your statement?
7. Which shows wilt first during a season of slight rainfall, a heavy or light crop? Why?

VERTICAL FARMING

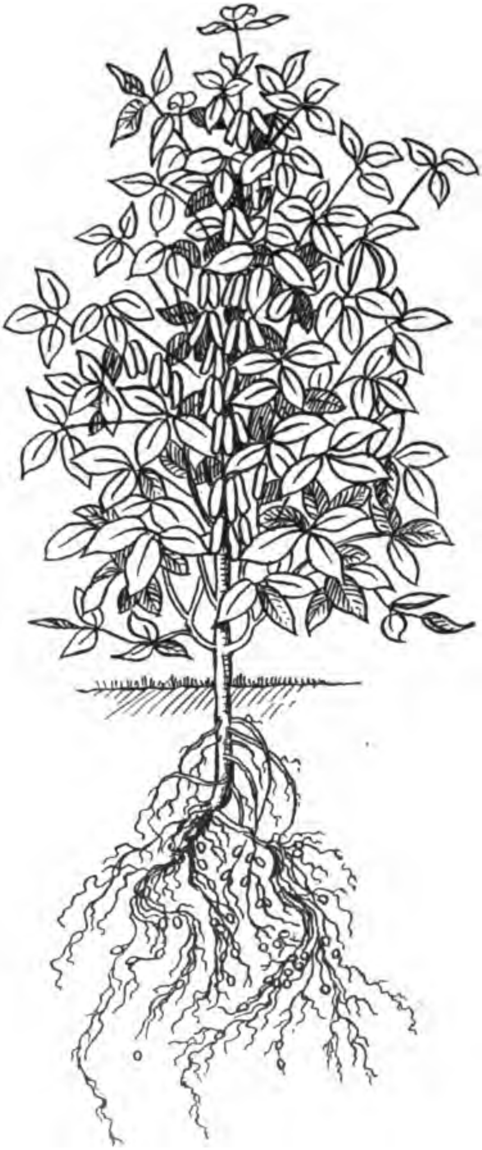
PART III

Soil Moisture

ITS CONTROL AND CONSERVATION

Crops must have sufficient amounts of water at the right time. The greatest demand for water is often during the season of least supply. The water must come from the feeding zone of the roots within the soil. No phase of agriculture is of more importance or worthy of more study than how to maintain an adequate supply of soil moisture. A soil may be rich in plant food and not have water enough to dissolve it and carry it to the plant roots. Nothing reduces the fertility of the soil and the yields of farm crops in the United States annually more than the lack of a proper supply of water at the season when the crops demand it. The rainfall may be deficient or too unevenly distributed so that the farmer is forced to store water somewhere and in some way. There are few sections of the country where this is not necessary; where there is rain enough during the growing season to water the crops. They must draw their supplies from reservoirs that are above or below ground, and the best of all is utilizing the soil itself as a reservoir.

Soil Water as a Plant Food.—All vegetable matter consists largely of hydrogen and oxygen, which elements are obtained from the soil water and combined with other elements in the plant itself. These combinations of the water forming elements, together with a small amount of carbon from the air, form by far the greater weight of domestic plants even when they are thoroughly dried. It is the water used as food that makes up



GOOD TOP AND ROOTS POSSIBLE ONLY ON A WELL DRAINED SOIL the greater part of all the starch, sugar and other similar compounds so valuable, in that they form one of the essential parts of the foods for men and lower animals.

Water as a Carrier of Plant Food.—All of the plant foods in the soil have first to be dissolved in water and then carried by it to and through the roots and up to the above ground parts of the plant. The tiny feeding roots must be immersed in the thin film of water that clings to the soil particles. The soil solution is absorbed into the rootlets through their walls and forced upward with a considerable pressure. This can easily be noticed by cutting off a rank growing weed and watching how quickly the sap is thrown up over the newly cut stump. This pressure is often several pounds per square inch. All the water that is not combined in the plant as a part of it is thrown out through the leaves, this process being called "transpiration."

If the moisture conditions of the soil are good and water is abundant, transpiration is encouraged and there is an attending satisfactory growth of crop; but if the conditions are reversed, the plant growth is immediately stunted by the deficiency in the amount of the essential water.

Amounts Necessary for Crops.—Taking crops altogether, from rice to date palms, the amount of water required varies from complete submergence to almost perpetual drouth, and within this range crops vary widely as to the amount necessary for living. As a rule the amount is large, as it is only the desert plants that thrive on a scant supply. Take a small potted plant and place it under a glass jar and notice how soon the jar is clouded by the water vapor taken up from the soil and given off through the leaves. From 200 to 600 pounds of water are transpired by ordinary crops for every pound of dry matter produced, but this varies with each crop according to the climate and other factors affecting it.

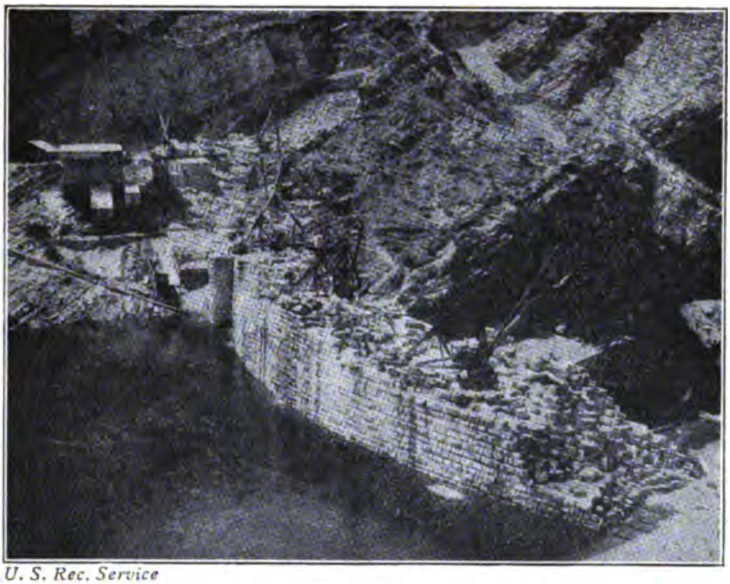
A good yield of pea vine hay will draw 1200 to 1500 tons of water through its roots and stems and liberate it in the air. Corn and cane drew equally heavily upon the soil supply of moisture.

The water required by a field of any of the ordinary field crops, if spread over the surface, would cover it to a depth of several inches, sometimes as much as a foot or more. This is only the water used by the plant itself, and does not include the amount that is lost by being evaporated or that passing too deep into the soil to be drawn back to the roots. In addition, a plant cannot take all of the moisture out of the soil in the range of its roots. In irrigated districts the amount of water applied to and absorbed by the soil often reaches an amount equal to three feet, and in some localities more.

This water used by the plant or lost by evaporation from the soil during rainless days must all come from the soil, and shows what care must be exercised in storing and holding all that is possible.

Water and Soil Temperature.—A uniform soil temperature is essential to the best growth of crops, and a soil properly supplied with moisture will change its temperature very slowly, while a dry, parched soil will quickly heat up during the day and cool off again as rapidly at night, and the crops will suffer accordingly. Coarse soils retain only a relatively small amount of moisture and are warm and early. Fine soils, like the clays, retain much more water and are cooler and later in the spring.

Storing Water.—Where irrigation is practised, reservoirs are used to store and hold water, but in most of the states this method is inadvisable. The best place to store the water for use in time of drouth is in the soil itself, by converting the subsoil of every acre into its own reservoir. This large storage may be assisted and encouraged in several ways. The first thing to do is to be sure to get the rain water down into the soil instead of allowing it to be wasted by running off on the surface, because it cannot enter a hard or impacted soil readily, if at all. Such soils may be found to be dry even after a heavy rain. In " dry farming," and also in farming where the rainfall is heavier, some practise rough plowing before the seasons of heavy rain to increase the absorption of rain water, and later harrow or drag the surface to form a mulch and prevent loss

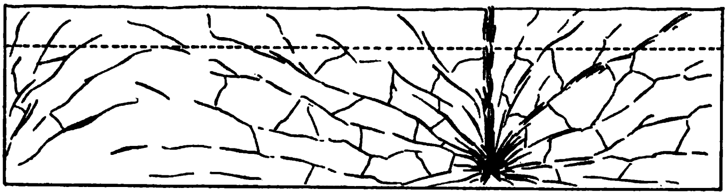


U. S. Rec. Service

IRRIGATION DAM—THE EXPENSIVE METHOD OF STORING WATER FOR PLANTS

through evaporation. Where this practice has been carefully followed, good has resulted, but ordinarily the depth to which plowing is possible is insufficient to reach the zone of the greatest trouble. Others have gone further and plowed deeper, using heavy tractors with subsoil plows. The results obtained have been variable, and it is quite evident that the efforts along this line, while well conceived and of benefit, have fallen short of their mark by not disturbing the soil to a sufficient depth.

In most cases of resistant soils, the trouble is at a considerable depth, in fact, below the depth that could possibly be reached by any form of plow. For relief then, there is nothing practicable but a rational use of a subsoiling explosive. This, like the subsoil plow, is used when the subsoil is dry, so that the force of the explosion will shatter and pulverize the subsoil rather than pack it into a more impervious mass. Usually this is in the late summer and early fall, when the plants have pumped all of the available water out of the soil. This season is followed by the fall and the winter rains which can then find their way deep into the cracks and fissures where they are absorbed and held indefinitely if proper care is given to the surface. The heavy rains following such a shattering of the subsoil have the additional advantage of resettling any parts of the soil where the explosion may have opened it up too much. In the spring and summer following such a soil treatment, the young roots find an easy path into the deeper soil, where they can continue to draw their full ration of water from the stored supply and thus nourish the crop during long seasons of drouth.



SUBSOIL SHATTERED BY A BLAST—THE CHEAP WAY OF STORING WATER FOR PLANTS.

Excesses of Water Must be Drained Away.—Field plants will not grow in a soil saturated with water. An ample supply is necessary and must be maintained, but a great deal depends on how the supply is kept up, or in other words, on the moisture condition. Land animals require water to drink, but perish if immersed in it, for the air necessary for their existence is then shut off. Plant roots die if the soil is saturated with water because their air is cut off. Fortunately, soil will hold only a certain amount of moisture if the water is free to move, the excess gravitating downward and draining away. This is called gravity of free water. The gravity water sinks until met and checked by impervious material or reaches standing water; that is the water table. Unless such free water sinks too deep, it is not entirely lost to the plant, as it not only sinks through gravity, but is also brought back to higher levels, when the top soil begins to dry, by capillary attraction, just as water climbs up a piece of cloth, one end of which is allowed to hang in water. This capillary water is the water that supplies the immediate demands of the plant. Some of the water collects on the surface of each soil particle and sticks to it with a peculiar force, forming a film over the soil grain. This "Film Water" is very important, for the force that holds it so closely to the grains enables it to dissolve the mineral plant foods in the particle and prepare them for absorption by the roots.

Air Must Circulate in the Soil.—The air in the soil is as essential to plant growth as the air above the soil. This soil atmosphere below the surface is heavier than the air above, and contains more carbon dioxide and similar compounds than our atmosphere. These gases are absorbed into the soil water and become a part of the attacking force that liberates the mineral foods from the dense minerals. The nitrogen supply of the

CYPRESS ROOTS THROW UP "KNEES" THROUGH WHICH TO BREATHE. FIELD CROPS CANNOT DO THIS SO THE EXCESS OF MOISTURE MUST BE DRAINED AWAY legumes is also drawn from the soil air. This air circulates through voids or pores which are stopped up by excesses of free water that cannot drain away. Such a condition stops the actions just described, and must be guarded against by keeping free water drained away from the active feeding zone of the roots. When the water table is within the reach of the deeper roots, small feeders are sent down to or near the water surface and drawn from the moister soil there.

Cultivation and Yields.—The easiest soil to plow or cultivate is one that has all excesses of free water drained away, and has dried a little so that it will crumble rather than break in lumps. A wet, soggy soil is not only hard to cultivate, but the very act of working it injures instead of being a benefit. The air is worked out, and the air spaces themselves are closed by the process, and the granulation is destroyed. A very dry soil breaks up cloddy, and the condition produced by plowing it when it is in this condition is sometimes nearly as bad as if it had been plowed wet. The proper storage of capillary moisture by good cultivation is the only safeguard to maintaining the proper tilth of the soil and to prevent puddling or the formation of clods.

The aim of the farmer is to produce crops at a profit. Water is the cheapest article he has to handle, and is at the same time one that allows itself to be handled almost at will, but becomes a serious drawback if allowed to take its own way. It must be there as a food and a carrier of other foods, as a control of the temperature of the soil, and to insure the proper granulation of the soil. Everything that can be done to the soil in the way of getting rid of excesses of free water and holding the maximum of capillary water will make itself known in the increased yields it affords.

Erosion.—Erosion or washing steals plant food. If bad, it takes the whole of the surface soil away. An excess of water often causes damage by erosion. In addition to taking away valuable plant food and the cultivated top soil, erosion leaves the fields cut up and rough and exposes material that requires

U. S. D. A.

A BADLY ERODED HILL

much effort and long exposure to weathering before the plant food reaches a satisfactory state of availability. Gentle, slow rains are always preferable, because they have more time to soak into the soil, but as the intensity of rainfall is beyond the control of the farmer, he must fortify his soil against attacks of erosion due to heavy precipitation or large amounts of rainfall in a short time. The answer is to get the water down into the soil before it can run off. It is a difficult matter to do this in a big wash, where thousands of barrels of water are coming down, but these large washes are started by little trickles of only a few spoonfuls further up the hill. These little trickles start because the soil is too tight for the water to enter. The surface may be sealed over by a little crust or there may be plow sole, tight clay, or hardpan deeper down which limits the soils absorption to the immediate surface. The correction of such conditions prevents the wasting of the valuable soil into the drainage courses. The surface crust can be destroyed with even the lightest tools, and a deep shattering by blasting will open up the subsoil so that it will be able to absorb hundred of gallons of water, where before it took but sparingly.

Clemson College S. C. Bulletin

EXPENSIVE TERRACING TO PREVENT EROSION

Drainage.—Attention has already been called to the necessity of removing all excesses of free water. Where such excesses are caused, as they so frequently are, by the water being held on or near the surface by hardpan or other impervious material below, the trouble may be overcome by breaking through the holding material into more open material below. The full extent of the possibilities of this method of drainage have not yet been developed, and it is quite likely that many of the upland swamps will later be entirely controlled by this method.

A more rapid development of the larger swamp areas has been retarded on account of the great expense of ditch digging by hand or by the machines suitable for digging under such conditions. Again, a rational use of dynamite has answered the question, for it has been absolutely proven by experimentation and practical application on large and small drainage areas that ditches can be quickly, economically and satisfactorily excavated by blasting. The wet soils of the swamps and overflowed regions have made digging by hand expensive on account of the difficulties encountered by the labor, but swamp water has no terror for the swift cutting action of a high power dynamite that will rip open a long stretch of large or small ditch at one effort. Such a blast not only opens the ditch, but levels down the harmful spoil pile or bank, scattering the dirt over the adjoining land for a distance of over a hundred feet.

A BEAUTIFUL BLASTED DITCH

Ditch blasting is by no means limited to wet lands, for it is being successfully used in excavating even in dry hill soil, provided it is not sandy. Changes in the soil or the soil condition require changes in the selection of the explosive and the method of loading, which are details that can best be learned from the books of practical instruction of the manufacturer or from one of their representatives.

The use of blasting in connection with drainage is not limited to the shattering of deep drainage courses to permit of downward drainage, but is being used largely in connection with open and blind ditches where the subsoil is so hard that it prevents the passage of the water into the drainage channels.

Thorough subsoil blasting opens up these subsoils and permits the drains to collect and carry away the water that has rendered the fields worthless.

Dynamite and farm powders are also being used to control old-established gullies or washes. The banks are shot down into the bottom of the gully so that teams can be driven across to plow the banks down to the desired level. This shattering also loosens deeply and increases the immediate absorption of water and benefits further by holding out of the surface drainage much of the water that before increased the run off and attending erosion.

QUESTIONS

1. What is the amount of the annual rainfall in your part of the state?
2. How is this distributed during the year?
3. Which of your crops suffer most from lack of water? Why?
4. Describe your ideal method of storing water on your farm for the use of crops?
5. What have been your experiences with deep plowing?
6. What is your method of controlling erosion, and what results have you obtained?
7. What modifications in your practice of controlling erosion do you think necessary?
8. Describe an ideal plan for the general drainage of your farm, that will include the control of the hill water as well as that of the bottoms.
9. What is the best method of correcting a small stream that has a crooked, shallow bed?

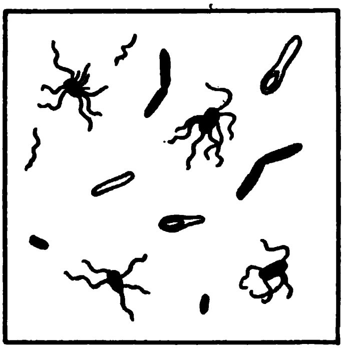
VERTICAL FARMING

PART IV

Soil Bacteria

The most constantly active part of the soil is its bacterial life. These are tiny little plants that are very close to the border line of being animals, and are known by a number of popular and slang names. They are the smallest known living organisms. Some are so small that 50,000 of them lying side by side would not measure over an inch, and a single drop of blood or milk would form a desirable tenement for thousands to live in and multiply. They reproduce very rapidly, usually in from 15 to 45 minutes. If unchecked, a single bacterium could multiply to 17,000,000 in 24 hours. This reproduction is seriously checked by lack of room, insufficient food and unfavorable surroundings, such as lack of air or too much water for some and the reverse for others. They are also checked in their development by the presence of their own excreta. They form spores for their reproduction and for preservation and distribution. In the spore stage they can live over long periods of conditions unfavorable for their growth and reproduction, and then begin their work again when conditions are favorable. The total number of bacteria is inconceivable, for they are in the air, water, soil, and everywhere.

Some of them are harmful, and their development should be checked, while others are so helpful to mankind that every effort should be made to encourage their growth. The different forms require widely different conditions for their best growth. One class thrives in an abundant supply of air, and are called "aerobic." Another form, "anaerobic," get their oxygen from breaking down compounds containing this element and thrive best in places that are not well ventilated. The first named form includes the beneficial forms of soil organisms, while those of the second class are usually harmful. The very cultivation and aeration of the soil, therefore, promotes the growth of the beneficial forms and checks the activities of the harmful ones. The deeper the soil is loose and well aerated, the deeper the helpful forms are found.



DIFFERENT FORMS OF BACTERIA (GREATLY ENLARGED)

Harmful Bacteria.—Some forms of bacteria produce destructive diseases in the plants, both in the tops and branches and in the roots. The greatest trouble from bacteria in the soil, however, comes from the forms that attack the nitrogen carrying foods and cause the nitrogen to be unlocked from its combined form and to escape as gas. These forms thrive best in wet and packed soil, where they cause the organic substances to undergo a wasteful putrefaction rather than a beneficial decay. Their activities are at once checked by the presence of free air. Some crops grown continuously on the same soil for a long time cause it to become filled with forms that cause diseases in the roots. Generally these can be destroyed by a rotation of crops attended with deep tillage.

In short the control of harmful soil organism is accomplished by thorough drainage and good, deep cultivation. Many of them seem to thrive best in sour soils which can be made sweet and desirable for the beneficial forms by additions of lime.

Beneficial Organisms.—Bacterial action is beneficial to agriculture in many ways. As soon as a plant or animal dies, the influences that have restrained the action of the organisms of decay are removed and the bacteria at once begin breaking down the complex organic substances into forms that are again suitable for plant food. In this way they are the health patrol, the scavengers of the soil. Some forms have the power of liberating food from the insoluble mineral soil grains and are the fairy chemists whose laboratory is the surface of the soil particles. These soil builders have already been described elsewhere is these articles.

In fact there are millions of these tiny forms that are eager and willing to assist the farmer and gardener if given proper soil atmosphere, proper soil moisture, and proper soil temperature.

Nitrogen Fixing Bacteria.—Attention has been called to the likelihood of a deficiency of nitrogen in the soil and the high cost of replenishing the supply through the use of expensive fertilizing materials. Certain of the air-loving bacteria form little colonies, called nodules, on the roots of leguminous plants and take the free gaseous nitrogen of the soil air and tie it up in compounds that furnish the nitrogen fertilizer to the higher forms of plants. These bacteria do not thrive in either a wet or a sour soil, and are not found naturally in the soils of many parts of the country. They can be planted or started in such soils by the use of certain commercial cultures, or by additions of soil in which they are known to be present. Abundant supplies of these bacteria are necessary in the soil before it is possible to get a good growth of the most beneficial legumes without robbing the soil of the supply of nitrogen al-

NODULES ON ROOTS OF A LEGUME

ready present in a properly combined form. Even in soils rich in nitrogen the growth of these crops is materially benefited by the presence of the bacteria.

Other forms of bacteria and kindred plants of microscopic size have the power of gathering bacteria from the soil air and their development should also be encouraged. These forms are not so well known as those that produce the nodules on the roots, but their benefits are marked. They demand a well drained and well aerated soil.

Helping a Friend Along.—Aside from the nodule forming bacteria, most of the other beneficial forms are found in all normal soils. It is not necessary to add them in artificial cultures, but their activities can be materially increased by keeping them in suitable surroundings and supplying their constant but simple desires. These forms get their oxygen from the air, and must therefore not be closed up in a tightly sealed soil. They do not thrive in the deep subsoil unless it is well aerated. Large excesses of water that clog up the pores of the soil also

SWAMP CONDITIONS OR EXCESSIVE AMOUNTS OF WATER SEAL THE SURFACE AND STOP BENEFICIAL BACTERIAL ACTION exclude the air and smother out the good forms, but permit the harmful bacteria to grow at will. While too much water is bad for them, too little water also retards their work. A good moist soil, just about what the plants want, is their favorite —in short, a well drained soil. Most of them need a supply of organic matter, such as partly decayed plants or animals. This is also just what the plants want. Another one of their desires is for even tempered soil, where the changes are not too sudden from hot to cold. Here again they agree absolutely with the plants. In fact the beneficial bacteria and plants seem to be such good friends and neighbors that anything that benefits one equally benefits the other, and if one feels sick, the other wants the doctor also.

In keeping up the bacterial activities care in turning under green manures or additions of litter or manure is always repaid many fold. These additions of humus forming material also assist greatly in maintaining the needed moisture supply as humus has a wonderful power of absorbing and holding water and also assists in granulating the soil.

More About Nitrogen.—Free nitrogen is everywhere. The air over a single acre contains about 75,000,000 pounds of this peculiar element. To buy a pound will cost from 15 to 20 cents.

TWO SOURCES OF NITROGEN
HOME TRAPPED BY LEGUMES—BOUGHT AT GREAT COST

The farmer, through his good little friends, the "bugs," traps and stores this in his soil, provided he goes about it in a business-like way.

This way is simple. Prepare the soil for the best content of moisture and air, and see that it is not sour. Be sure that the right bacteria are present, and then grow deep rooted legumes that suit the locality best. Selections of legumes can be made for practically any purpose. Some of them yield the most nutritious hay, while others furnish grain that is good for food for both man and all kinds of farm animals. Others furnish excellent pasture. Some are best suited for soil building in the shape of green manure.

The deeper the preparation of the soil the better the results that are obtained. A few inches of loose soil will give just so much room for these activities. A few inches more will be of benefit, but the desired production cannot be reached until the air-loving bacteria and the deep-rooted plants have several feet of good mellow soil in which to operate. The only satisfactory method of effecting such deep tillage is by blasting.

A ROTTING LOG. BACTERIA MAKE HUMUS OUT OF EVEN THE LARGEST AND HARDEST PARTS OF PLANTS

QUESTIONS

1. Are the changes due to the rotting of a plant or animal under water the same as rotting in the air?

2. What are the most noticeable differences you have detected in the two kinds of rotting?

3. What are five beneficial effects of bacteria on the farm?

4. What are five harmful effects of bacteria on the farm?

5. How would you prepare a bottom having a cold, wet subsoil, and drained by a deep open ditch, for growing ordinary field crops?

6. How would you prepare a tight hillside subsoil, low in lime, for growing alfalfa?

VERTICAL FARMING

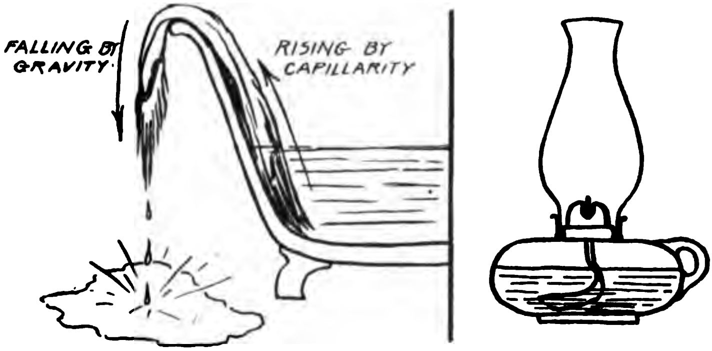
PART V

The Movement of Moisture and the Feeding Zone of Roots

The movement of moisture in the soil is of the utmost importance to plants. It is first necessary that the water received from rain or irrigation should move downward through the soil, leaving behind only such as is held by capillary attraction. The excess should move out of the soil and into the drainage. This movement of moisture is entirely one of gravity. Water moving in this way is called " free water."

Movement of Water by Gravity.—In order to get the water down into the subsoil and prevent its running away as surface drainage, or standing on the surface and stopping all possibilities of air circulation through the soil pores, it is essential that it move downward very soon after it is deposited on the surface. This movement depends on the openness of the soil. Sometimes in a sandy soil the water soaks into the soil too rapidly and too much drains away, but such is not the case with clay and other dense soils. In such soils the pores are naturally small and the water is held back. The movement can be hastened by tilling or stirring the soil to the depth to which it is desirable to carry the water. The deeper this can be made effective the better, and so it is very apparent that soils where the water is likely to stand on the surface are in need of the deepest practical tillage. As the free water clogs the pores and stops many of the soil processes, the plants do not draw their moisture from it, but get it instead from the smaller capillary supply left behind.

Movement of Capillary Water.—The capillary or film movement of moisture takes place in all directions, but its most important direction is upward. When tight soils prevent the downward percolation of free water, some is carried downward by this pull which has been described elsewhere as the same movement as the oil moving in a wick. As the amount of moisture that is held by capillarity is limited and if not replenished, the supply within reach of the roots may soon be exhausted. This available supply is partially maintained by the upward movement of capillary water. As one point becomes dry, the water is drawn from below by a constant pull on the thin film. When capillary water moves from the more abundant supply below, it brings with it soluble plant foods to assist in nourishing the plant.

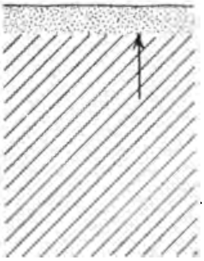


TWO EXAMPLES OF CAPILLARITY

The movement of capillary water is effected by several conditions. It is governed very largely by the texture of the soil. The finer the soil and the more surface the soil particles expose, and the more points of contact between the particles, the greater is the pull. For example, a heavy clay soil containing 20 per cent. of moisture may draw water from a coarse sand containing only 10 per cent. Sandy or coarse soils move water very rapidly and in large amounts, but the movement in such soils cannot take place over long distances. With clay, which has a much stronger capillary pull, the movement is much slower, but may take place over greater distances against gravity. The amount of moisture moved in this way decreases as the limit of distance is reached.

In addition to the texture, the structure of a soil has an important part in governing the capillary movement. The better granulated a heavy soil, the greater the pore space and consequently the greater the pull. Additions of humus materially increase the capillary pull as well as the reservoir capacity of a soil. In a puddled soil the movement is very slow and the amount of water moved very small. The denser the soil becomes, the slower the movement.

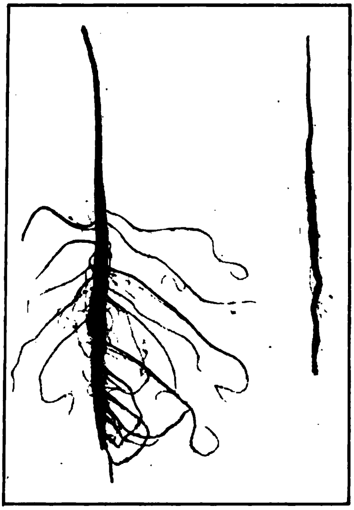
Dry layers of soil break off the capillary pull on account of the coating of the soil particles being of such a nature that they resist wetting. It is this fact that makes the effectiveness of a dry dust mulch, in holding the water below the surface and not allowing it to rise to the surface and be lost by evaporation. Capillary movement is much faster in wet or moist soils than in dry ones, so it is advisable at all times to preserve some moisture in the soil if only for its benefits in a rapid equalization of the moisture content when water is applied. The ratio of the movement in wet and dry soils has been shown to be as high as 1 to 4.



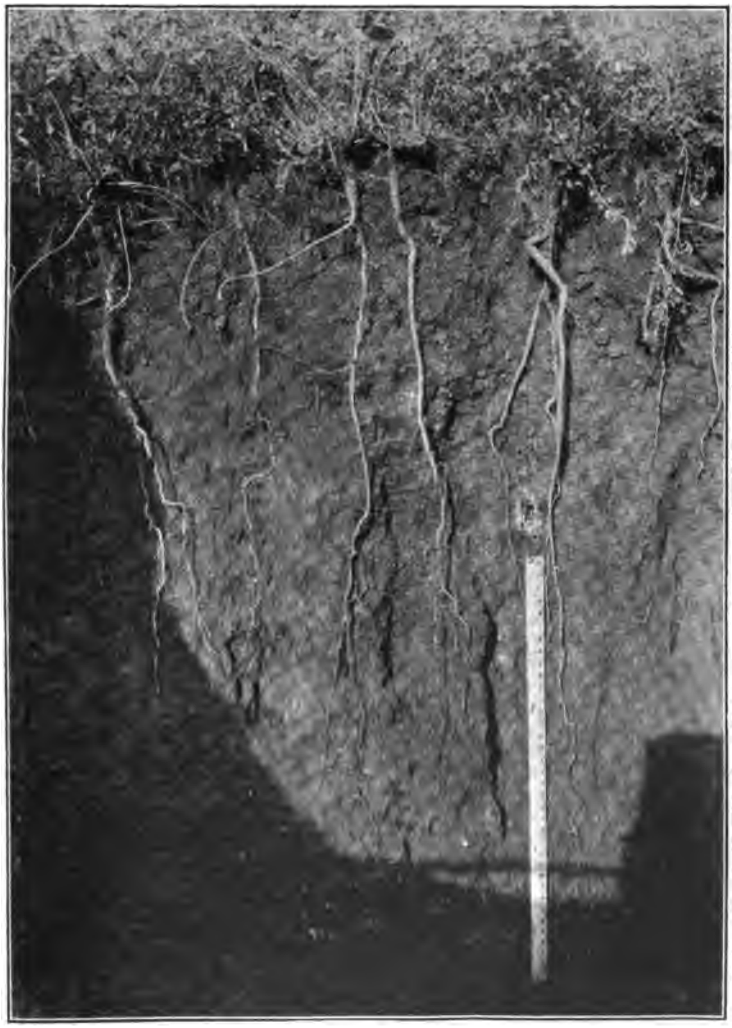
THE CAPILLARY RISE OF MOISTURE CHECKED BY A DUST MULCH

This upward movement continues to the surface and when allowed to go unchecked will result in all the movable moisture being pulled up and lost by evaporation. The rate of evaporation of moisture from the surface is governed largely by temperature and wind velocity. When water is stored at great depths in the soil it is harder for it to be pulled to the surface and lost. This surface loss at times approximates an amount equal to a sheet of water 5 inches deep, over the whole surface in a month. A handy example of the upward movement of water and a check to its loss can be observed by turning over an old log or plank that is lying on the ground and noticing the large amount of water in the soil immediately underneath.

The Feeding Zone of Roots.—The root systems of plants require as ample room in which to develop as does the stalk and leaf system above. Roots must both anchor the plant in place and reach down for food and water. The feeding zone of a plant determines the amount and value of the top. The soil must be cultivated in order to provide a proper feeding zone, for the earth in its natural condition will not yield as abundantly as well cultivated soil. Just below a good surface mulch in a well cultivated field we find moist soil full of roots revelling in an ideal feeding zone. On an adjoining uncultivated field one must dig down to find moist soil, and discovers only a few roots feeding in a meager compact feeding zone. Rootlets are ever pushing into fresh soil zones where more water and food are to be found, yet the feeding zone in ordinary farming is confined largely to the shallow depths of the plowed furrow, simply because it is the only warm, mellow, well ventilated soil within the reach of the roots. When given a chance, feeding roots advance rapidly to meet the capillary rise of soil moisture, and the energetic way in which they go down and search in every direction for food and water proves them to be highly organized parts of the plant and possessed of instinct or something akin to intelligence. Plants having large or active root systems, making a rapid growth, remove more water and more plant food from the soil in a given time than those with a small system or



PECAN ROOTS FROM BLASTED AND TIGHT SOIL

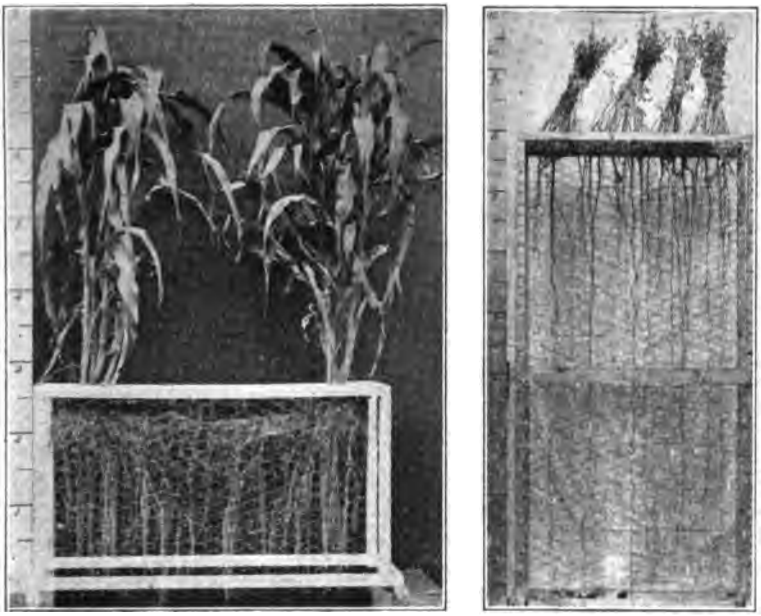


ROOTS GOING DOWN FOR FOOD AND WATER. THE DEEPER THE BETTER.

sluggish action. A corn crop when in the season of most vigorous growth will remove more water from the soil in a day than will a crop of wheat. Some crops are slow, weak feeders, while others feed ravenously, and, while taking up more substance, may be able to overcome more unfavorable conditions. Roots should be thrown down into the soil as far as possible in order to get away from danger of drouth, and excesses of temperature, as well as from injury by cultivating machinery.

The desirable conditions for a root system can be improved by thorough cultivation of the subsoil, much deeper than any plow can go, by means of explosives. They loosen up the soils so that the roots are not checked in going downward, the rise of capillary water is aided, aeration is improved, and deep reservoirs of water made accessible. This method more than doubles the depth of the feeding zone.

Depths to Which Roots Go.—The natural tendency of most roots is to go deep into the soil. Many who have not investigated this subject believe that roots do not go deeper than one or two feet and cutivate accordingly. On the contrary, they go to much greater depths if the soil conditions permit. Corn roots that have been confined and have occupied all the soil to a depth of 2 feet, will go to a depth of 8 feet if the restriction is removed. Wheat, oats and barley will penetrate from 8 to 10 feet, grass roots will go down 6 and 8 feet, while alfalfa has been known to go down over 30 feet. Grapevine roots have been found 22 feet below the surface, while the root systems of trees correspond in extent and branching to the parts above ground. The roots of clover weigh as much as the total weight of the year's crops, while the roots of an oat crop are nearly 50 per cent. of the weight of the seed and straw. The total length of all the roots of a wheat plant was found to be about 268 feet, of one rye plant 385 feet, and of one corn plant 1452 feet. Such facts show that the size and depth of the root systems are generally not appreciated, and are generally underestimated. It is evident that the roots need a far deeper feeding



Courtesy Prof. Ten Eyck, Kas. Expt. Sta.

DEEP ROOTING OF CORN AND ALFALFA

zone than is ordinarily given them. The feeding zone has been shallow and meager, largely because the farmer could formerly find no suitable means for the deep cultivation. No practical machinery can till the soil as deep as 2 feet, and even that limit is not sufficient for the needs of crops. Such deep cultivation is possible only with high explosives.

The benefits of deep rooting of a crop do not pass away when the crop is harvested, for the roots are left down where they grew, and on decaying form humus at a depth where it would be impossible to place it by artificial means, down where it will help to perpetuate the granulated condition of the subsoil, and keep alive the deep feeding and working bacteria, helping the farmer to gain thereby the full return from all of his field rather than from the top only.

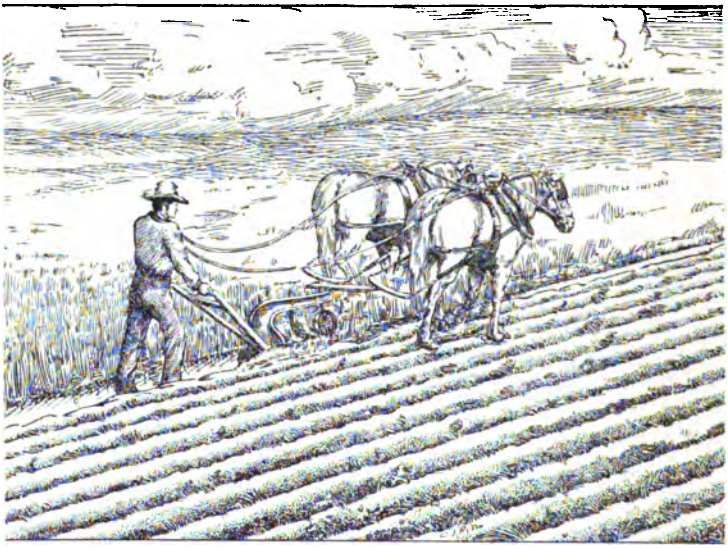
Weeds and Their Effects.—Weeds injure crops by robbing them of their water and food. The escape of water is intangible, like the setting free of plant food, because we cannot see either with the eye and must put our wits to work to detect its departure. Weeds may have a mission in life; anyway they are stimulating rascals. When the farmer gets mad enough to go after them, their mission is ended, for by destroying them he conserves the moisture by unconsciously cultivating the ground and increases the fertility of the soil.

WEEDS—THE STAR BOARDERS

Conserving the Moisture.—Where the moisture supply is deficient, weeds should not be allowed at any time before, during, or after the crops, for they remove water from the soil as rapidly as the useful plants. When the water is ample, but the soil too fine to permit rapid enough capillary movement, green manure should be grown and plowed under deeply. The chief feature in conserving moisture is, of course, to get the moisture in hand. This can only be done by leading it down into the soil to great depths. If the soil is of such a nature that this takes place of its own accord, all well and good, but many soils are not that way. They are stubborn, and need a real first-class shooting with an explosive to subdue them. Then the maintenance of the organic matter and surface mulch can reach their desired effects.

QUESTIONS

1. What soil conditions cause water to be held on the surface of fields?
2. Will oil rise faster in a moist or dry lamp wick? Will the same principle always hold true of soils?
3. Why does a dry layer of soil stop the capillary rise of moisture?
4. When should a dust mulch be renewed?
5. What effect would a few inches of loose straw on the surface have on the soil moisture during a rain? During hot, dry weather?
6. Why is it beneficial to fall plow and deep till thin, hard lands and cover the surface with trash?
7. Which will you find at greater depths, wheat or clover roots?



THE PLOW GIVES THE IDEAL SURFACE BREAKING BUT ONLY EXPLOSIVES CAN ATTACK THE DEEP TROUBLES

VERTICAL FARMING

PART VI

Cultivation—Use of Explosives

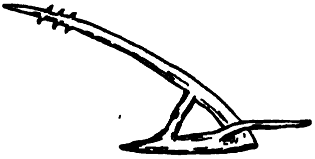
The present means and methods of cultivation are behind the times. They are not up to date with the progress made all along other lines. They all work too shallow, cultivating the land a few inches where they should loosen and stir to a depth of several feet. A world of wealth in thought, money, invention and machinery has been bestowed upon the first few inches of the soil at the surface, but up-to-date agriculture demands that the depths of the soil be considered also. It is not enough to just scratch the surface and leave untouched the storehouse of wealth below.

A World of Tools.—The farmer has at his command for working this thin skin of the surface inches a wonderful array of tools. He has plows of all kinds and qualities to select from to fit every surface condition imaginable—hillside, landside, hinge, and swivel plows—equipped with every shape of moldboard, and coulters that may be fin, knife or rocking. He may use hand, sulky, or motor plows, and work them single, double, or in gangs. He has harrows without number, home-made and latest patent, coulter, spring, chain, slicing, spading and cutaway, all of them equipped with teeth set vertical or set slanting, with plain, twisted, shovel, coulter, spike, and spring teeth in a bewildering dental display. He has cultivators of all sorts and breeds—hand, walking, and riding. He has drags, rollers, plankers, floats, boats, clod crushers, pulverizers, and smoothers, and he has so-called subsoilers in good variety that work only a few inches deeper than the tools already mentioned.

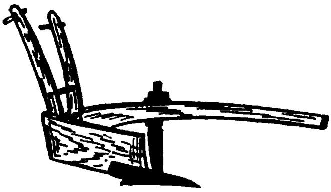
Yet with all this to select from he can do but little better than the Romans did—prepare the seed beds and scratch the surface, while at greater depth the roots still have to scratch for themselves, as they did centuries ago. It is too much on the principle of the man who only greased the front wheels of his wagon, saying that if they went the hind ones would " just naturally have to follow."

Progress Demanded.—With lands becoming scarce and prices higher, there is a demand for methods that are more efficient, that will cultivate the ground to greater depths, that will meet the demands of the feeding roots, that will double the feeding zone, that will furnish deep moisture reservoirs, that will extend bacterial activity downward, that will double and treble the farmer's acreage of productive soil by depth, and not by area. So far as these demands are concerned, farm machinery is so far a failure and but little advance has been made on the primitive plow, the sharp stick with a V-branch. It is not

MARVELOUS IMPROVEMENTS HAVE BEEN MADE IN SURFACE CULTIVATION enough to secure ease of draft, or raise heavier and faster walking horses. It is not enough that the ox, horse and mule are giving way to steam, gasoline, and electricity, to cable traction and automobile luxury. It is not enough to point with pride from the one-negro-one-mule-one-plow combination to the monster steam gang plows. Something more is demanded. The present machinery is good *so far as it goes,* and is the best that the world has ever seen until recently, but *it does not go far enough.* It does not go down. Many remedies have been suggested only to meet with a cold reception. It is always difficult to change old conditions, old customs, for there is ever prejudice against such changes. The kind of prejudice that the first cast iron plows (Newbolds, 1797) " poisoned the land " and " caused weeds to grow " is still in existence, and can only be overcome by enlightenment.



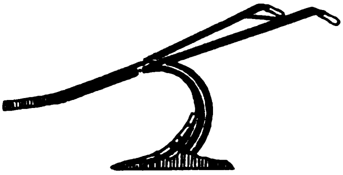
PLOW USED BY THE ANCIENTS



EARLY AMERICAN TYPE

Shallow Methods Prevail.—All methods and machinery in common use are good for preparing the seed bed, but are of little or no use in helping the roots to go down to their natural length; of no use in improving the soil atmosphere more than a foot or two, or in meeting the many and varied demands of the plant system below the surface. The function of the plow is essentially to turn a thin ribbon of the soil on edge or upside down, and to shatter and break the surface of the earth as much as possible, and to destroy weeds, and bury refuse. Harrows and cultivators have primarily a stirring action that forms mulches and prevents surface evaporation, but they work at even shallower depths than the plow. Some of the instruments used tend to form plow sole, or hardpan and impacted conditions of the soil close to the surface, defeating the very object of cultivation.

The most effective of all farm tools in breaking up the surface soil is the plow, and its use in working up a tight surface soil into a satisfactory condition of tilth must never be overlooked. The effectiveness of the plow has been improved by using modifications that will disturb the soil to greater depths than is possible with an ordinary moldboard plow. The best known tool of this type is the narrow subsoil plow that follows along in the freshly turned furrow of the regular plow, deepening the cultivation several inches. Such a plow does not bring the subsoil to the surface but simply stirs the subsoil. The depth reached is seldom as much as 18 inches and is usually not more than 12 to 14 inches. A more improved implement is the new double disc Spaulding Deep Tilling Machine, which combines in one tool both the surface

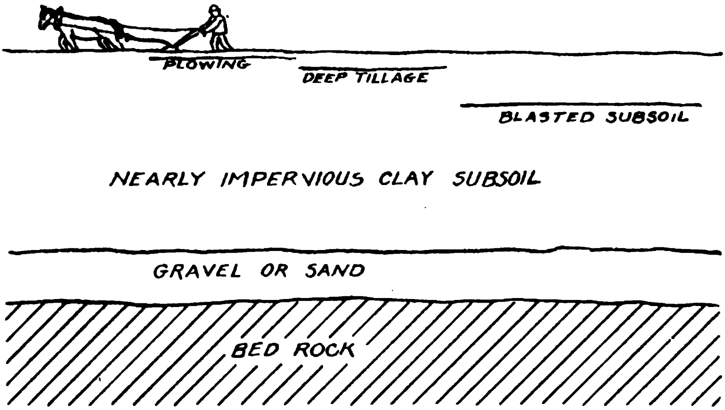


COMMON SUBSOILER

SPAULDING DEEP TILLING MACHINE

and the sub-surface plow. One heavy disc follows behind and below another, and by their cutting, twisting action break and mix the surface soil with a layer of the material lying underneath. Excellent results have been obtained with both forms of deep plows, and their use is strongly recommended, as their immediate action is to break up the plow sole or shallowest hardpan material. They also leave the surface and immediate sub-surface in a most desirable condition to receive the rain water and allow it to be conducted to the deeper subsoil that has been shattered with an explosive, where it may be held by capillary absorption.

Benefit of Using Explosives.—It is admitted that present methods of cultivation do not go deep enough, and it must also be admitted that the use of specially prepared agricultural explosives offers the desired remedy. It is admitted by all authorities in agriculture that the plow and harrows do not go deep enough and they advise the use of subsoilers. Scores of books explain how and why each piece of machinery turns over the soil, reduces it to fineness, forms mulches, saves water, breaks clods, aerates, stimulates bacteria, etc. If all this wealth of invention and labor *is worth while bestowing upon the first few inches* of the soil why it is not worth *following the roots*



COMPARATIVE DEPTHS REACHED BY DIFFERENT FORMS OF TILLAGE *down* to their second foot of growth, their third, and even their eighth and tenth foot when they flourish at those depths. The only reply is, " Yes it would pay, but how can it be done? ". It can be done economically, quickly, and thoroughly by the use of explosives. Deep plowing is recommended by all authorities " wherever the resisting soil will permit." Machinery made especially for deep work may be stopped, but nothing can resist the explosives. The farmer plows, harrows, and spends time, labor and money in cultivating the surface foot and rejoices in the wonderful alchemy that follows his endeavors—the mysterious activities he has set in motion. He works cheerfully and with confidence, largely because he can see what he is doing. In the new agriculture he must work by faith and reason in depths where he cannot see with his eyes what is taking place. The result will place before his eyes in the form of bumper crops proofs of the benefits of his work. The new agriculture simply points out the benefits acquired by the thorough cultivation of the foot, or two feet, and by explaining how and why this is accomplished, points out the value of extending the cultivation further down by the simple means of explosives. The harrow warms and aerates the soil and promotes activity by loosening and separating the soil particles at the surface. Explosives do the same, breaking, loosening, pulverizing at depths machinery cannot reach. Drainage is recommended by all because it removes excess of water, admits air, and gives proper moisture conditions. Explosives have drained many a field and secured all these benefits at far less cost in time, labor and money than the usual methods of ditching and tilling.

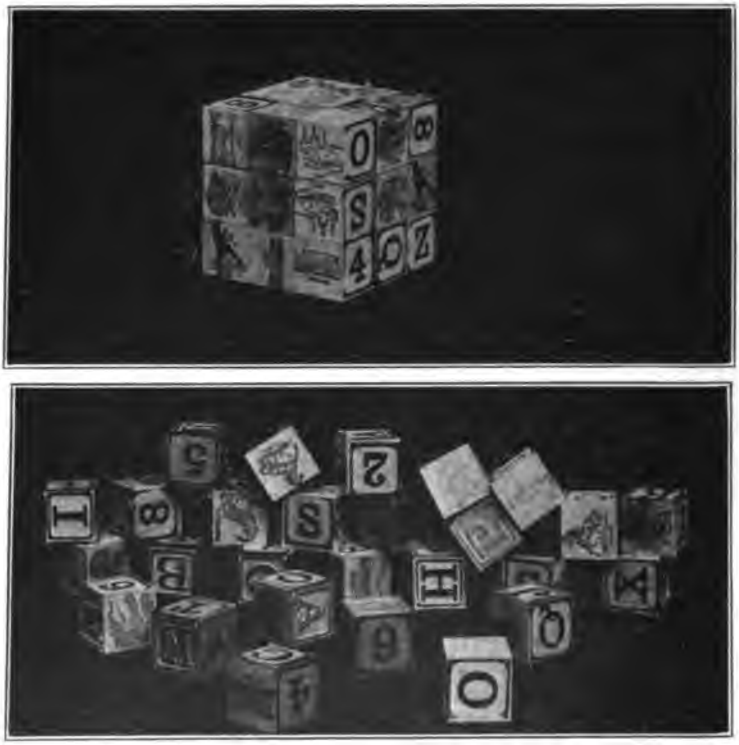
The importance of nitrification is proven, but why confine it to the thin furrow slice when the action of bacteria has been proven at depths of 6 feet in the humid soils of the East, and still deeper in the porous soils of the arid and semi-arid regions of the West? Why not loosen the soil and secure proper conditions by the use of some charges of explosives? It is admitted that there is much of plant food below the shallow plowed and cultivated ground, and that the roots will go down if they can. Why not open the way and make it easy for them by cracking and pulverizing the soil with explosives as far down as the roots care to go? It is admitted that water may be stored, as in dry farming, by converting the soil itself into a reservoir by making it porous so that it absorbs water and holds it like a sponge. Why not use explosives and make the reservoirs two and three times as great and secure absolute instead of partial insurance against drouth?

It is admitted that much of the rainfall is lost by running off, and consequent damage done by erosion. Why not check this by the use of explosives before the rainy season, storing the rainfall in porous soil instead of letting it run to waste? It is admitted that some of the soils called "wornout," or "poisoned" and "worthless" may be reclaimed if the soil is thoroughly stirred up from the depths. What can do this so efficiently as explosives? It is admitted that much of the plant food in the soil is unavailable because it is unweathered. Why not make it available by opening the ground to weathering agencies by explosives?

FROM DEEP SHATTERED SUBSOIL

The benefits of clean summer following every other crop, under low rainfall, and occasionally under abundant rainfall are admitted. Why not secure these benefits by means of explosives? It is admitted that granulation of a soil is a benefit, that any treatment that increases the lines of weakness in the soil structure facilitates the movement of capillary water, and the action of moisture films. The more numerous the lines of weakness the quicker granulation is secured.

The fewer the lines of weakness the more close and cloddy the structure. What will granulate soil to the depths quicker than explosives? It is admitted that present machinery can only increase the feeding zone of the roots an inch or two. What can explosives do in this line? A cubic yard of hard soil has 6 faces and 9 square feet in each face, or a total of 54 square feet. Divide it into 1 foot cubes and there are 162 feet of surface. Break it into inch cubes and it presents 1944 square feet, or nearly 1/20 of an acre of feeding surface for the roots.



TOY BLOCKS TO REPRESENT THE INCREASE IN SURFACE AREA—THE REPRESENTED CUBIC YARD HAS A SURFACE AREA OF 54 SQUARE FEET. THE 27 CUBIC FEET A SURFACE OF 162 SQUARE FEET. IF BROKEN TO INCH CUBES THE AREA IS 1944 SQUARE FEET

SHATTERING SUBSOILS WITH FARM POWDER

A single cartridge of explosive can easily convert several yards of compact and useless hardpan into *half an acre* of new feeding ground. Costly, massive, improved machinery enables the farmer to spread out his operation, to move horizontally, and handle more acreage in the same time, and he is ever eager to double and treble his holdings of fertile soil. What is wanted is something that enables him to move vertically down and double his acreage, and double his yield by doubling the fertility of the soil, by doubling the depth of the feeding zone, by doubling the water supply, by cultivating the ground to double and treble the former depths. "*Vertical Farming*," to coin a name, is the keynote of a new agriculture that has come to stay, for inexpensive explosives enable the farmer to farm deeper, to go down to increase his acreage, and to secure larger crops. Instead of spreading out over more land he concentrates on less land and becomes an intensive rather than an extensive agriculturist, and soon learns that it is more profitable to double the depth of his fertile land than to double the area of his holdings, and he learns that his best aid and servant in this work is a good explosive. Peace congresses demand that swords be turned into pruning hooks. The farmer is busy turning explosives from war to agriculture, from death dealing to life giving work.

There is a demand to-day for farmers who think, and who think long and closely as well as observe; for men who reject nothing because it is an innovation, because it is new. Men are wanted everywhere who have thought for themselves how soil first came into being and what its form and character are and what they mean; men who are not satisfied until they know how plants feed, where they feed, and the nature of their food; men who look below the surface of the ground and realize that as much of their future crop is there as will be above the surface, that plant roots must have air and water at the right times and in the right abundance as much as the animals in their barns.

This kind of men have been and are using explosives freely as the best and simplest means of securing success and accomplishing their object. Their success may be duplicated by all who care to do so. The use of explosives for deep cultivating and other farm purposes has come to stay.

Vertical farming with explosives is another step forward as truly as irrigation and dry farming, and is greater, for unlike them it is not limited to any area or region but may be practised everywhere and anywhere. It has the world for its field.

QUESTIONS

1. What is your investment in tools per acre of land tilled?

2. What is your total cost of preparing, seeding, cultivating, and harvesting one acre of money crop?

3. What improvements over the practices of your father have you made in the use of field machinery and supplies?

4. How deep do you actually plow? (Measure the depth at the unbroken side of the furrow.)

5. Did you ever follow up the full development of the roots of a tree or a field plant? What did you find?

6. Have you any actual knowledge of the character of your subsoil?

Commonwealth of Pennsylvania

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but the latter may easily be reduced to an excellent condition. As a rule the soil is well drained. Most of the rain readily percolates through the soil into subterranean channels formed by the decomposition of limestone, which provides a most excellent drainage system. There is very little surface run-off and the surface wash is reduced to a minimum.

In some places this type of soil is marked by a number of ponds, which may be due to one of two causes. The sink holes into which the surface water disappears may be so clogged that the water cannot get away, or a substratum of the impervious clay may be responsible for holding the water. Although this type of soil was formed by the decomposition of rock containing about seventy per cent. of calcium and magnesium carbonates, yet because these minerals are soluble in drainage water the soil may often be deficient in lime.

VOLUSIA SILT LOAM.

This type of soil is of glacial formation, so that it is variable in composition and thickness. The predominating color is gray. The subsoil may be yellow, gray, brown, or a mottled gray and yellow. In swampy land the surface soil may be black or dark gray, while the subsoil may be very light in color. On steep areas the soil is generally stony, consisting largely of sandstone or shale rock. The silt loam on level or gently rolling lands may be comparatively free from stones. In general the Volusia silt loam consists of from six to eight inches of gray or brownish gray silt loam, with a subsoil of light gray or mottled gray and yellowish silty loam. The percentage of clay of the lower subsoil usually increases with depth, a clay mixture replacing the silty clay loam. Therefore a section of soil often includes three well defined classes of soils in successive layers.

The drainage is often very deficient in this type of soil. In such cases artificial drainage must be provided before crops can be profitably grown. In many localities large areas are covered with ponds during wet seasons and in many cases the ponds are permanent. Where adequate drainage is maintained, and sufficient lime is added to correct the soil acidity, and good farming methods are practiced, fair crops may be expected from this type of soil.

The object in conducting these experiments was to determine:

1. General physical effect on soils.
2. Effect on soil moisture and drainage.
3. Effect on newly planted fruit trees.
4. Effect on mature trees.
5. Effect on field crops.
6. Effect on insects and fungous diseases as far as could be determined.

The dynamite used in these experiments was obtained from the E. I. du Pont de Nemours Powder Company, Wilmington, Delaware. In the orchard and field crops, Red Cross twenty per cent. dynamite was used; in shooting swamps, Red Cross forty per cent. dynamite was used; in shooting an open ditch, Red Cross sixty per cent.

Hercules dynamite was used. It was the aim to make all explosions as heavy as could be used without scattering the soil to an undesirable extent. The amount of dynamite required was also a part of the investigation.

Experiment No. 1.

To Determine the Effect of Dynamite on Newly Planted Fruit Trees.

Young apple trees were planted in holes over the spots where dynamite had been exploded in the soil. Check rows of trees were planted at both ends of the plats in holes where no dynamite had been exploded. Measurements of the circumference and height of each tree were taken at planting time and at the end of the growing season, so that any difference in growth between trees planted on dynamited soils and soils not dynamited could be readily detected. The measurement of each tree was taken just above the surface of the ground. This experiment was conducted on two different farms in Lawrence county. One was the farm of Arthur H. White, of Pulaski, and the other was the farm of J. H. Johnston, of New Wilmington.

Experiment No. 1A.

Experiment with Newly Planted Apple Trees on the Farm of Arthur H. White, Pulaski, Pennsylvania.

On May 8, 1912, fifty-three one-year-old Baldwin apple trees were planted thirty-four by forty feet apart, except the first eighteen, which were sixteen feet apart. Numbers 1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 20, 21, 22, 23, 49, 50, 51, 52, and 53 were planted in holes where no dynamite had been used. Numbers 2, 4, 6, 8, 10, 12, 14, 16, and 18 were planted in holes where ⅓ of a half pound stick of dynamite had been exploded two feet below the surface of the soil. Trees from 24 to 48, inclusive, were planted in dynamited holes. The depth of explosion and the size of charge is shown in the following plan. The soil was dry enough to plow and was in good working condition. The circumference and the height of each tree were measured and the weight of each of the first eighteen trees was taken.

Arrangement of Trees and Treatment.

Check row, ...	....	0 53	0 52	0 51	0 50	0 49	0 18	0 17
Size of Charge.								
1-3 stick, ...	Depth of Explosion. 2 feet, ...	0 48	0 47	0 46	0 45	0 44	0 16	0 15
1-3 stick, ...	2 ft. 6 in., ...	0 43	0 42	0 41	0 40	0 39	0 12	0 11
1-2 stick, ...	3 feet, ...	0 38	0 37	0 36	0 35	0 34	0 10	0 9
2-3 stick, ...	3 ft. 6 in., ...	0 33	0 32	0 31	0 30	0 29	0 8	0 7
1 stick, ...	4 feet, ...	0 28	0 27	0 26	0 25	0 24	0 4	0 3
Check row, ...	....	0 23	0 22	0 21	0 20	0 19	0 2	0 1

On November 26, the first six trees were dug up and the roots and tops were weighed separately. On the same date, measurements of the circumference and height were taken for all the trees. The following tables show the measurements taken before and after the growing season and the weight of each of the first six trees.

TABLE I.—Influence of Dynamiting on Growth of Young Trees (White Experiment).

(A) Trees Planted in Holes not Dynamited.

Weight November 26.

Trees.	Weight at planting.	Weight of top	Weight of root.	Total weight.	Gain in weight per tree.
	oz.	oz.	oz.	oz.	oz.
1,	10	10	10	20	10
3,	10	6	5	11	1
5,	10	7	5	12	2
Averages,	10	7.7	6.7	14.3	4.3

(B) Trees Planted in Dynamited Holes.

Weight November 26.

Trees.	Weight at planting.	Weight of top	Weight of root.	Total weight.	Gain in weight per tree.
	oz.	oz.	oz.	oz.	oz.
2,	12	7	7	14	2
4,	10	6	6	12	2
6,	....	Dead.	....	....	....
Averages,	11	6.5	6.5	13	2

(C) Trees Planted in Dynamited Holes.

Trees.	Circumference, May 8, 1912	Circumference, Nov. 26.	Growth.	Height, May 8.	Height, Nov. 26.	Growth.
	in.	in.	in.	in.	in.	in.
2,	2.25	2.50	.25	30	34	4
4,	1.62	1.75	.13	33	38	7
6,	....	Dead.	....	....	....	....
8,	....	Dead.	....	....	....	....
10,	2.38	2.50	.12	31	32	1
12,	....	Dead.	....	....	....	....
14,	2	2.06	.06	30	36	6
16,	2.12	2.50	.38	30	34	4
18,	2.06	2.38	.32	38	62	24
Averages,	....	....	.207	....	....	7.67
24,	....	2 (Replanted)	....	....	50	....
25,	2.12	2.38	.25	31	33	2
26,	2.50	2.62	.12	38	18	....
27,	2	2.56	.56	29	36	7
28,	....	Dead.	....	....	....	....
Averages,	....	....	.31	....	....	4.50
29,	....	Dead.	....	....	....	....
30,	1.75	2	.25	36	46	10
31,	2.19	2.75	.56	32	42	10
32,	1.44	2.06	.62	32	32	0
33,	....	Dead.	....	....	....	....
Averages,	....	....	.477	....	....	6.67
34,	....	1⅞ (Replanted)	....	....	34	....
35,	....	Dead.	....	....	....	....
36,	....	1⅞ (Replanted)	....	....	29	....
37,	....	Dead.	....	....	....	....
38,	....	....	....	....	....	....
39,	2.12	2.50	.38	38	32	....
40,	1.75	1.75	0	30	34	4
41,	2.62	2.75	.13	33	44	11
42,	1.50	1.62	.12	43	34	....
43,	2.25	2.62	.37	35	53	18
Averages,	....	....	.20	....	....	11
44.	....	1.88 (Replanted)	....	....	32	....
45,	Dead.	....	....	....	....	....
46,	....	2	(Replant	ed)	29	....
47,	Dead.	....	....	....	....	....
48,	....	1.88	(Replant	ed)	36	....
General averages,	....	....	.272	....	....	7.71

(D) Trees Planted in Holes Not Dynamited.

	in.	in.	in.	in.	in.	in.
1,	2.38	2.62	.24	31	33	2
3,	2	2.12	.12	25	35	10
5,	2.38	2.44	.06	30	41	11
7,	2.62	2.88	.24	30	42	12
9,	2.50	2.62	.12	34	39	5
11,	1.88	2	.12	32	36	4
13,	2	2.12	.12	30	32	2
15,	1.88	2.06	.18	37	45	8
17,	2.25	2.50	.25	24	24	0
Averages,	....	....	.16	....	....	6

(D) Trees Planted in Holes Not Dynamited.—Continued.

Trees.	Circumference, May 8, 1912	Circumference, Nov. 26.	Growth.	Height, May 8.	Height, Nov. 26.	Growth.
	in.	in.	in	in.	in.	in.
19,	2	2.12	.12	30	32	2
20,	2.50	2.62	.12	30	34	4
21,	2.50	2.69	.19	34	53	19
22,	1.50	1.56	.05	28	30	2
23,	Dead.	....	....	....	....	....
Averages,	....	....	.12	....	....	6.75
49,	2.12	2.62	.50	30	36	6
50,	1.38	1.88	.50	21	14	....
51,	Dead.	....	....	....	....	....
52,	1.94	2	.06	46	35	....
53,	1.31	2.50	1.18	31	42	11
Averages,	....	....	.56	....	....	8.50
General average,	....	....	.25	....	....	6.53

The care given these trees during the summer was very poor. Some died and the tops were cut off of a few others. The care given will account to some extent for the great variation in growth.

These tables do not show any appreciable difference in growth between the trees planted in dynamited soil, dynamited at 2 ft., 2 ft. 6 in., 3 ft., 3 ft. 6 in., or 4 ft. in depth. Comparing the trees planted in dynamited soil with those planted in soil not dynamited, there is a growth in circumference of .272 in. to .25 in. or .022 in favor of trees grown in dynamited soil, while of the growth in height there is 7.71 in. to 6.53 in. or 1.18 in. in favor of the trees grown in dynamited soil. In circumference and in height, the growth is in favor of the trees grown in the dynamited soil. In both cases the difference is small, in fact no more than would be naturally expected in measuring a lot of trees, especially those given rather poor care.

Experiment No. 1B.

Experiment with Newly Planted Apple Trees on the Farm of J. H. Johnston, New Wilmington, Pennsylvania.

On May 9, thirty-five one-year-old Langford apple trees were planted forty by forty feet apart. Numbers 1 to 5 and 31 to 35, inclusive, were planted in holes where no dynamite had been exploded. Numbers from 6 to 30, inclusive, were planted in holes where dynamite had been exploded. The ground was very wet at the time the dynamiting was done and the trees were planted. The circumference and the height of each tree were measured. The depth of explosion and the size of charge are shown in the following plan:

Size of Charge.	Depth of Explosion.					
Check row,		0 31	0 32	0 33	0 34	0 35
1 stick,	4 ft.,	0 26	0 27	0 28	0 29	0 30
2-3 stick,	3 ft. 6 in.,	0 21	0 22	0 23	0 24	0 25
1-2 stick,	3 ft.,	0 16	0 17	0 18	0 19	0 20
1-2 stick,	2 ft. 6 in.,	0 11	0 12	0 13	0 14	0 15
1-3 stick,	2 ft.,	0 6	0 7	0 8	0 9	0 10
Check row,		0 1	0 2	0 3	0 4	0 5

The following tables show the measurements taken at planting time and at the end of the growing season:

TABLE II.—Influence of Dynamiting on Growth of Young Trees (Johnston Experiment).

(A) Trees Planted in Dynamited Holes.

Trees.	Circumference, May 9.	Circumference, Oct. 12.	Growth.	Height, May 9.	Height, Oct. 12.	Growth.
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
6,	1.62	*1.62	0	33	30	....
7,	1.25	1.75	.50	30	48	18
8,	1.75	1.88	.13	33	57	24
9,	1.25	1.68	.44	31	49	15
10,	1.50	1.62	.12	33	44	11
Averages,	....	....	2.38	....	....	17
11,	1.75	2	.25	32	54	22
12,	1.25	1.50	.25	31	34	3
13,	1.50	1.75	.25	34	49	15
14,	1.50	1.62	.12	34	38	4
15,	1.62	1.88	.26	33	42	....
Averages,	....	....	.225	....	....	10.60
16,	1.38	1.50	.12	31	39	8
17,	1.50	1.75	.25	31	42	11
18,	1.50	1.88	.38	33	48	15
19,	1.38	1.50	.12	33	36	3
20,	1.25	1.39	.13	30	38	8
Averages,	....	....	.20	....	....	9
21,	1.75	1.99	.19	36	37	1
22,	1.62	1.69	.07	34	43	9
23,	1.88	2	.12	37	45	8
24,	1.62	1.69	.07	34	41	7
25,	1.50	1.88	.38	32	42	10
Averages,	....	....	.166	....	....	7
26,	1.88	2.06	.18	35	44	9
27,	1.62	2	.38	33	54	21
28,	1.38	1.50	.12	32	47	15
29,	1.50	1.81	.31	31	39	8
30,	1.62	1.88	.24	31	44	10
Averages,	....	....	.25	....	....	12.60
General average,	....	....	.215	....	....	11

*Top dead.

(A) Trees Planted in Holes not Dynamited.

Trees.	Circumference, May 9.	Circumference, Oct. 12.	Growth.	Height, May 9.	Height, Oct. 12.	Growth.
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
1,	1.25	1.50	.25	34	43	9
2,	1.62	2	.38	28	48	20
3,	1.12	1.56	.44	30	47	17
4,	1.38	1.62	.24	36	50	14
5,	1.62	1.88	.24	35	60	25
Averages,	....	....	.31	....	....	17
31,	1.75	1.88	.12	38	47	9
32,	*1.38	1.38	0	31	33	Dead.
33,	1.75	1.88	.12	35	47	12
34,	1.50	1.62	.12	35	42	7
35,	1.50	1.62	.12	31	50	19
Averages,	....	....	.12	....	....	11.75
General average,	....	....	.203	....	....	14.67

*Top dead.

The ground was very wet when these trees were planted and it remained in a wet condition the greater part of the summer. The care given the trees was good. The ground was frequently cultivated and kept clean from weeds throughout the growing season.

These tables do not show any appreciable difference between the growth of trees planted on soil dynamited at depths of 2 ft., 2 ft. 6 in., 3 ft., 3 ft. 6 in., or 4 ft. Comparing the circumference of trees planted in dynamited soil with those planted in soil not dynamited, there is .203 in. to .215 in. or .012 in. in favor of the trees planted in dynamited soil, while in height there is 14.67 in. to 11 in. or 3.67 in. in favor of the trees planted in soil not dynamited. The difference in circumference amounts to nothing. The difference in height is too small to be significant.

Experiment No. 2.

Rejuvenating Apple Trees.

To Determine the Effect of Dynamiting on Mature Fruit Trees.

This experiment was conducted in two orchards with conditions practically the same. Both orchards were in Lawrence County. One orchard belongs to J. B. Johnston, New Wilmington, Pa., and the other to J. A. Boak, R. F. D. No. 4, New Castle, Pennsylvania. In both orchards, Red Cross twenty per cent. dynamite was exploded in the soil on three sides of mature apple trees. The depths of the explosions varied from two to four feet. The circumference of each tree was measured just above a nail driven in the tree about eighteen inches from the ground. These measurements were taken at the time of the dynamiting and at the end of the growing season. The tables for each experiment show the depths of explosions, the size of the charges, the yield of fruit, and the per cent. of color. The record of the dynamited trees is compared with that of similar trees in the same orchard, growing on the same soil and receiving like treatment, but not dynamited.

Experiment No. 2A.

Experiment with Mature Apple Trees in the Orchard of J. B. Johnston, New Wilmington, Pennsylvania.

For this experiment, ten Baldwin apple trees about twenty-five years old were selected. All the trees, dynamited and not dynamited, were fertilized with stable manure. On May 9, the circumference of each tree was measured and Red Cross twenty per cent. dynamite was exploded in the soil on three sides of five of the trees. The depths of the explosions and the size of the charges are shown in the following plan:

Check Row.	Neutral Row.	Dynamited Row.	Depth of Explosion.	Size of Charge.
10 0	0	5 0	4 ft.,	1 stick.
9 0	0	4 0	3 ft. 6 in.,	2-3 "
8 0	0	3 0	3 ft.,	2-3 "
7 0	0	2 0	2 ft. 6 in.,	½ "
6 0	0	1 0	2 ft.,	½ "

0 Represents the location of trees.

The following table is a record of the measurements taken May 9 and Oct. 12:

TABLE III.—Influence of Dynamiting on Mature Fruit Trees (Johnston Experiment).

(A) Trees Not Dynamited.

Trees.	Circumference May 9.	Circumference Oct. 12.	Growth.
	Inches.	Inches.	Inches.
Check Row.			
10,	44.75	45.50	.75
9,	39	40.75	1.75
8,	45.75	47.25	1.50
7,	44.25	44.75	.50
6,	40.25	41.62	1.37
Average,			1.175

Dynamited Row.

Trees.	Circumference May 9.	Circumference Oct. 12.	Growth.
5,	34	35.25	1.25
4,	31.25	32	.75
3,	47.50	49	1.50
2,	38	39.38	1.38
1,	45	45.50	.50
Average,			1.075

On October 12, the fruit was gathered, weighed, sorted and the per cent. of color was determined as shown in the following tables:

(B) Trees Dynamited.

Trees.	Pounds of Fruit Picked.	Pounds of Fruit Fallen.	Total.
1,	1004 lbs.	30 lbs.	1034 lbs.
2,	1092 "	33 "	1125 "
3,	1404 "	69 "	1473 "
4,	703 "	39 "	742 "
5,	714 "	43 "	757 "
Average,	983 2-5 lbs.	42 4-5 lbs.	1026.2 lbs.

Wt. of sample.	No. of apples.	Average weight.	Colored one-half or more.	Colored less than one-half.	Per cent. colored one-half or more.	Per cent. colored less than one-half.
163 pounds,	541	479 oz.	241	300	44.55%	55.45%

(C) Trees Not Dynamited.

Trees.	Pounds of Fruit Picked.	Pounds of Fruit Fallen.	Total.
6,	872 lbs.	28 lbs.	900 lbs.
7,	1188 "	72 "	1260 "
8,	1289 "	52 "	1341 "
9,	267 "	4 "	271 "
10,	1035 "	22 "	1057 "
Averages,	930.2 lbs.	35 3-5 lbs.	965.4 lbs.

Weight of sample.	No. of apples.	Average weight.	Colored one-half or more.	Colored less than one-half.	Per cent. colored one-half or more.	Per cent. colored less than one-half.
210 pounds,	795	4.23 oz.	470	325	59.1%	40.9%

These tables indicate that among the dynamited trees the depth of explosion had little or no effect on either the growth of the tree or the yield of fruit. In growth of the circumference, there is 1.8 in.

to 1.08 in. or .1 in. in favor of the trees not dynamited, while in yield of fruit for each tree there is an average of 1026 pounds per dynamited tree to 965 pounds per tree not dynamited, or 61 pounds in favor of the dynamited trees. The tables show a great variation in the yield of different trees of both the dynamited row and the row not dynamited. This variation is no more than might occur when selecting trees at random. The results prove nothing but indicate that there is a possibility that dynamiting may increase the yield of fruit.

Experiment No. 2B.

Experiment with Mature Apple Trees in the Orchard of J. A. Boak, R. F. D. No. 4, New Castle, Pennsylvania.

For this experiment, ten Baldwin apple trees about twenty-five years old were selected. All the trees, those dynamited and those not dynamited, were fertilized with stable manure. On May 14, the circumference of each tree was measured and dynamite was exploded in the soil on three sides of five of the trees. The depth of the explosions and the size of the charges are shown in the following plan:

Check Row.	Neutral Row.	Dynamited Row.	Depth of Explosion	Size of Charge.
10 0	0	5 0	4 ft.,	1 stick.
9 0	0	4 0	3 ft 6 in.,	2-3 "
8 0	0	3 0	3 ft.,	½ "
7 0	0	2 0	2 ft. 6 in.,	½ "
6 0	0	1 0	2 ft.,	1-3 "

The following table is a record of the measurements taken May 14 and October 14:

TABLE IV.—Influence of Dynamiting on Mature Fruit Trees (Boak Experiment).

Trees.	Circumference May 14.	Circumference Oct. 14.	Growth.
	Inches.	Inches.	Inches.
Check Row.			
10,	41.25	43.12	1.87
9,	41	41.88	.88
8,	38.75	40	1.25
7,	36	37.38	1.38
6,	35.50	36	.50
Average,			1.176
Dynamited Row.			
5,	43.50	45.38	1.88
4,	39	41.62	1.62
3,	36.50	37.88	1.38
2,	30.75	31.75	1
1,	34.50	35.50	1
Average,			1.376

On October 14, the fruit was gathered, weighed, sorted, and the per cent. of color was determined as shown in the following tables:

(B) Trees Dynamited.

Trees.	Pounds of Fruit Picked.	Pounds of Fruit Fallen.	Total.
1,	147 lbs.	43 lbs.	190 lbs.
2,	7 "	1.5 "	8.5 "
3,	267 "	37 "	304 "
4,	136 "	44 "	180 "
5,	89 "	29 "	118 "
	129.2 lbs.	30.4 lbs.	160 lbs.

Weight of Sample.	No. of apples.	Average weight.	Colored one-half or more.	Colored less than one-half.	Per cent. colored one-half or more.	Per cent. colored less than one-half.
95½ pounds,	363	4.21 oz.	297	66	81.8%	18.2%

(C) Trees not Dynamited.

Trees.	Pounds of Fruit Picked.	Pounds of Fruit Fallen.	Total.
6,	276 lbs.	62 lbs.	338 lbs.
7,	223 "	39 "	262 "
8,	146 "	46 "	192 "
9,	137 "	25 "	162 "
10,	281 "	54 "	335 "
Averages,	212.60 lbs.	45.2 lbs.	25.78 lbs.

Weight of Sample.	No. of apples.	Average weight.	Colored one-half or more.	Colored less than one-half.	Per. cent. colored one-half or more.	Per cent. colored less than one-half.
112 pounds,	428	4.19 oz.	348	80	81.3%	18.7%

These tables do not show that the depth of explosion had any influence on the growth of the trees or the yield of fruit. In circumference there is 1.376 to 1.176 in. or .2 in. in favor of the dynamited trees, while in yield of fruit for each tree there is an average of 258 pounds to 160 pounds or 98 pounds in favor of the trees not dynamited. This variation is no more than would be expected when selecting trees at random. The results prove nothing, but indicate very strongly that the dynamite had little or no influence on either yield or growth during the first year.

In these two experiments, the results are not very conclusive. In Experiment A, the yield of fruit was in favor of the dynamited trees, while in Experiment B, it was in favor of the trees not dynamited. In Experiment A, the circumference growth was in favor of the trees not dynamited, while in Experiment B, it was in favor of the dynamited trees. In Experiment A, the per cent. of apples colored one-half or more was greater for the trees not dynamited, while in Experiment B, there is a fraction of a per cent. in favor of the dynamited trees. These results may indicate that the dynamite had no effect, but it would be interesting to watch the results for another year or more.

Experiment No. 3. Subsoiling.

To Determine the Effect of Dynamiting on Field Crops.

This experiment was conducted on two farms representing two types of soil. The Pennsylvania State College farm in Centre County represents the Hagerstown clay loam and the farm of J. H. Johnston, New Wilmington, Lawrence County, represents the Volusia silt loam. Corn was the crop grown in both cases as it is a convenient crop on which to keep exact records. The dynamite explosions were made in rows and ran in the same direction as the corn rows. A record of yield was kept of each separate row of corn, so that any variation of yield between those planted on dynamited soil and those planted on soil not dynamited could be determined.

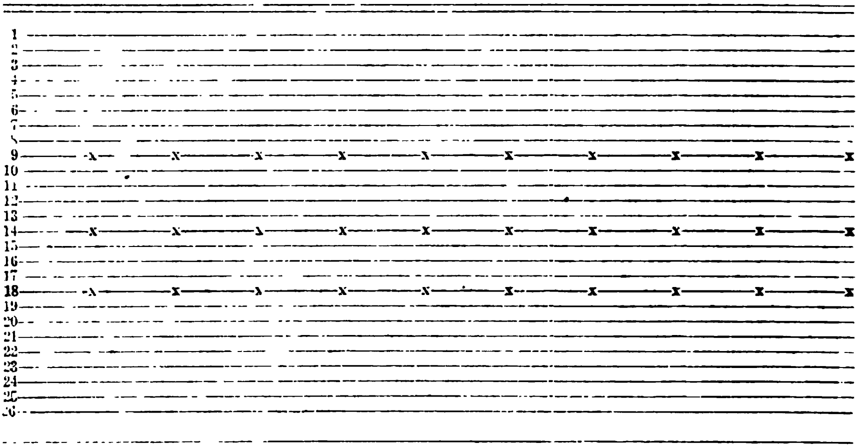
Experiment No. 3A.

Experiment in Dynamiting Soil for Corn on The Pennsylvania State College Farm.

The soil is a Hagerstown clay loam such as has been previously described. The natural drainage has always been considered very good, since there has never been any evidence of poor drainage. The plat was in an old sod field that had been used for pasture. The dynamiting was done by Mr. A. B. Burkholder, a professional demonstrator for the E. I. du Pont de Nemours Powder Company. The soil was dry enough to plow and was said to be in proper condition for dynamiting.

The explosions were made about fifteen feet apart in three rows which were fifteen feet apart and which ran lengthwise of the plat. A charge of about two ounces of dynamite was placed in a hole about three feet deep and exploded by means of a cap and fuse. The ground was plowed June 3, and living white grubs were abundant. The corn was planted soon afterwards and was cut October 23, fairly well matured, since no hard frosts occurred before October 10. The plat was two hundred and sixty feet long and eighty-seven feet wide.

The corn rows were three and one-third feet apart. The following map and tables will show the position of the dynamite explosions and the yield of each row of corn.



x Indicates position of explosion.

TABLE V.—Influence of Dynamiting on Yield of Corn (State College Experiment).

Rows.	No. of ears.	Wt. of corn.	Average wt. of ears.	No. of stalks.	Wt. of fodder.	Average wt. per stalk.
		Lbs.	Oz.		Lbs.	Oz.
1, ...	190	88.6	7.3	203	87	6.9
2, ...	202	84.6	6.7	219	102 wet	7.4
3, ...	203	84.9	6.7	218	83	6.2
4, ...	175	77.5	7.1	197	92	7.5
5, ...	193	82.8	6.9	209	85	6.5
6, ...	195	74.8	6.1	222	85	6.1
7, ...	183	76.0	6.6	222	101	7.3
8, ...	196	78.4	6.4	203	82	5.5
9, ...	188	82.3	7.0	211	88	6.7
10, ...	204	81.1	6.4	223	84	6.0
11, ...	197	81.1	6.6	225	97 wet	6.9
12, ...	196	77.6	6.3	216	78	5.8
13, ...	207	85.3	6.6	214	81	6.1
14, ...	199	71.1	5.7	212	77	5.8
15, ...	203	86.4	6.8	220	74 dry	5.4
16, ...	217	89.5	6.6	206	80	6.2
17, ...	189	84.8	7.1	201	93	7.4
18, ...	200	84.7	6.8	215	85	6.3
19, ...	196	83.3	6.8	213	84	6.2
20, ...	209	89.5	6.9	223	98	7.0
21, ...	205	94.5	7.4	211	105	7.9
22, ...	185	89.7	7.8	213	106	7.9
23, ...	195	89.9	7.4	215	90	6.7
24, ...	185	88.9	7.7	212	118 wet	8.4
25, ...	207	94.1	7.2	218	100	7.3
26, ...	199	101.4	8.2	219	126 wet	9.2
Averages, ...	196	84.7	6.9	213.8	91.6	6.9

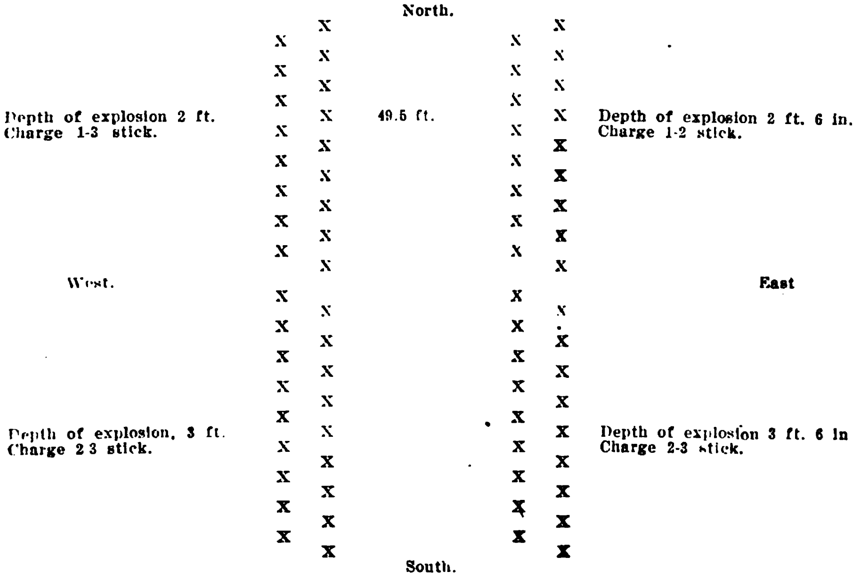
The above results show little if any difference between the rows planted on the dynamited soil and those planted on soil beyond the influence of the explosion. It is probably safe to conclude that dynamiting is of little if any value on soils well drained and in proper physical condition. If it has caused any increase in fertility by aeration, by increasing the available plant food, or in any other way, the amount has been too small to be noticeable. The abundance of white grubs would also indicate that its use is not very detrimental to insects.

Experiment No. 3B.

Experiment in Dynamiting Soil for Corn on the Farm of J. H. Johnston, New Wilmington, Pennsylvania.

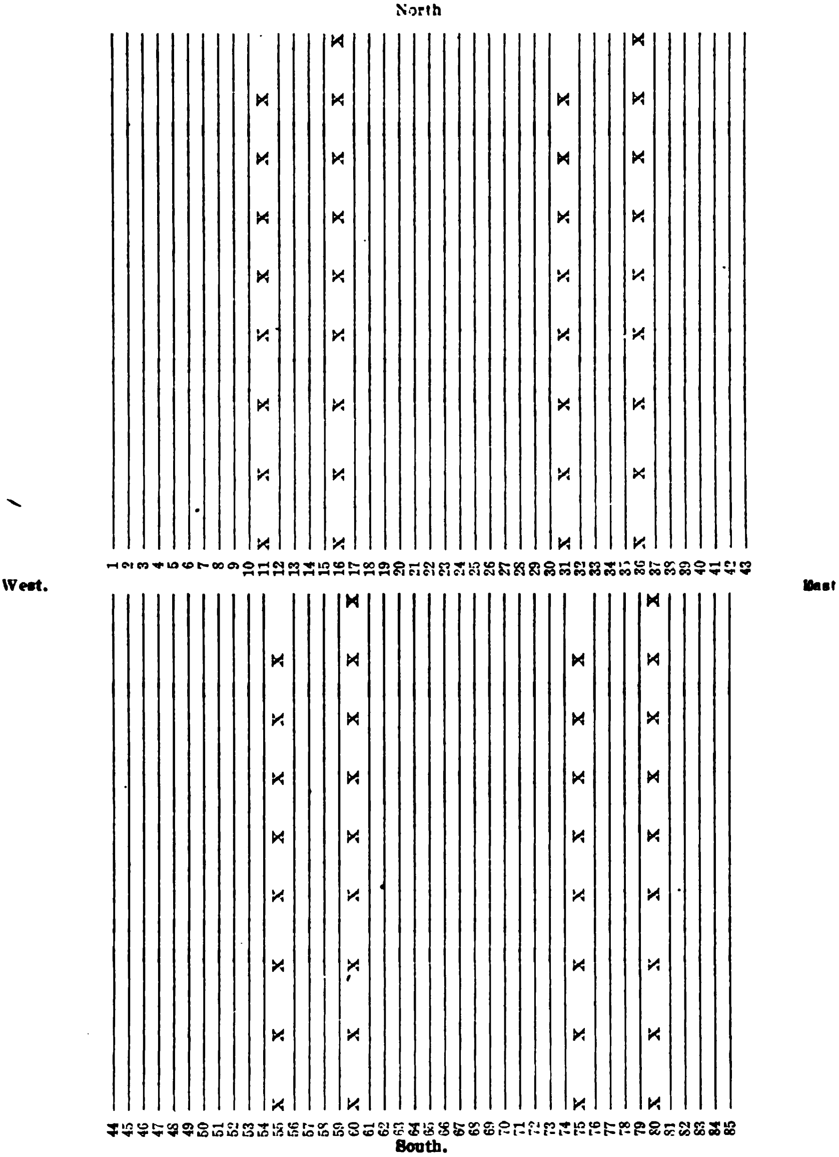
The soil is a typical Volusia silt loam such as has been described. The natural drainage is considered poor. A hard impervious subsoil hinders the proper movement of water. The plat was in a sod field from which hay had been cut three years. The ground was very wet at the time the dynamiting was done, and was in a wet condition most of the summer.

The plat was divided into four parts. The depth of explosions and the size of charge were different for each division of the plat. In each one there were two rows of explosions sixteen and one-half feet apart in the row. The following plan shows how the plat was divided, the size of the charge, the depth of explosion, and the position of the explosion.



The plat extended thirty-three feet west of the west row of shots and thirty-three feet east of the east row of shots. The corn rows were three and one-half feet apart. A separate record was kept for each row of corn. The numbers begin with the north section of the plat starting with row number one, thirty-three feet west of the west row of shots and ending with row forty-three about thirty-three feet east of the east row of shots. Row forty-four starts the south section about thirty-three feet west of the west row of shots, and ends with row eighty-five about thirty feet east of the east row of shots. Each row was eight rods long; no record was kept of the corn grown between the north and south division of the plat.

The following map shows the location of the rows and the location of the explosions.



X Shows location of explosion.

The following table shows the record of each separate row:

TABLE VI.—Influence of Dynamiting on Yield of Corn (Johnston Experiment).

Rows.	Number of ears.	Weight of corn.	Average weight per ear.	Weight of fodder.
		Lbs.	Oz.	Lbs.
1,	78	36	7.3	....
2,	73	38	8.3	....
3,	74	40	8.6	....
4,	63	42	10.7	....
5,	94	52	8.9	....
6,	93	53	9.1	....
7,	101	61	9.7	....
8,	65	38	9.3	....
9,	66	32	7.8	....
10,	69	41	9.5	....
11,	74	34	7.3	....
12,	47	19	6.5	....
13,	73	44	9.6	....
14,	76	36	7.6	....
15,	96	55	9.2	....
16,	67	41	9.8	....
17,	55	30	8.7	....
18,	62	31	8.0	....
19,	59	21	5.7	....
20,	41	18	7.0	....
21,	63	34	8.6	....
22,	63	32	8.1	....
23,	73	38	8.3	....
24,	67	37	8.8	....
25,	65	34	8.4	....
26,	64	32	8.0	....
27,	70	41	9.4	....
28,	56	36	10.3	....
29,	54	30	8.9	....
30,	70	41	9.4	....
31,	76	46	9.7	....
32,	87	51	9.4	....
33,	87	42	7.7	....
34,	70	40	9.1	....
35,	80	43	8.6	....
36,	67	38	9.1	....
37,	76	35	7.4	....
38,	65	38	9.4	....
39,	70	38	8.7	....
40,	72	39	8.7	....
41,	99	45	7.3	....
42,	74	40	8.7	....
43,	68	33	7.7	....
44,	72	34	7.6	23
45,	74	34	7.4	25
46,	55	22	6.4	22½
47,	69	34	7.9	28
48,	77	41	8.5	29
49,	65	33	8.1	28
50,	58	23½	6.5	24
51,	75	32	6.8	26
52,	66	22	5.3	22
53,	55	18	5.2	20
54,	39	14	5.7	15
55,	81	36	7.1	28
56,	66	28	6.8	24
57,	51	24	7.5	20
58,	69	33	7.7	28
59,	77	38	7.9	39
60,	74	30	6.5	26
61,	66	32	7.8	27
62,	66	22	5.3	17
63,	60	21	5.6	19
64,	61	24½	6.4	20
65,	67	33	7.9	24
66,	64	37	9.3	....
67,	73	35	7.7	....
68,	66	30	7.3	....
69,	67	32	7.7	....
70,	67	35	8.4	....
71,	67	36	8.6	....

TABLE VI.—Continued.

Rows.	Number of ears.	Weight of corn.	Average weight per ear.	Weight of fodder.
		Lbs.	Oz.	Lbs.
72,	64	31	7.8	....
73,	53	23	6.9	....
74,	48	20	6.7	....
75,	57	26	7.3	....
76,	73	32	7.1	....
77,	58	27	7.4	....
78,	61	29	7.6	....
79,	62	25	6.5	....
80,	55	23	6.7	....
81,	71	37	8.3	....
82,	65	35	8.8	....
83,	73	34	7.5	....
84,	63	31	7.9	....
85,	59	28	7.6	....
Averages,	67.9	33.9	7.9	....

The ground in this experiment was plowed May 24 and planted June 1. Cut worms were said to be as plentiful on the dynamited soil as elsewhere. Mr. Johnston also reported that he was also hindered in plowing and cultivating by the horses stepping into the holes made by the explosions. From the above results it is probably safe to conclude that the dynamite had little, if any, beneficial effect. The soil was wet when dynamited and remained wet. The dynamited ground from all reports was as wet as the ground not dynamited. It cannot be said that the results would not have been different in a dry soil, but under conditions such as existed dynamiting could not be considered profitable.

Experiment No. 4. Drainage.

To Determine the Effect of Dynamiting on Swamp Land.

This experiment was conducted on two ponds in Lawrence County. The conditions appeared to be similar, but after investigation they proved to be different in some respects. Both ponds were in the Volusia silt loam which has been previously described.

Experiment No. 4A.

Experiment in Dynamiting a Swamp Belonging to D. H. Byler, New Wilmington, Pennsylvania.

This pond is in an open field near the house. It covers about three-fourths of an acre, about half of which was dynamited. The water in the part of the pond dynamited did not exceed two feet in depth, but in no place was it less than one foot deep, except near the edge of the pond. The water was about the same depth in the part not dynamited, except in one place it was about two and one-half feet deep. The top soil is a black clay loam about twelve inches deep containing a large amount of decaying vegetable matter. Beneath this is a layer of fine blue clay, which would not permit the water to escape. Beneath the clay there is a coarse sandy material. At one time, perhaps fifty years ago, this pond was drained with stone drains, but they have long since ceased to be of any value.

On May 10 and 11, about fifty charges of forty per cent. dynamite were exploded in the subsoil under the pond. The explosions were from fifteen to twenty feet apart and varied from four and one-half to seven feet in depth. Most of them were from four and one-half to five feet in depth. The size of the charges varied from two to three half-pound sticks of dynamite. About one hundred and twenty-five sticks were used in the work. The dynamite was exploded by use of an electric blasting machine.

During the twenty-four hours in which the work was being done, the water in the pond fell one-fourth of an inch. It is not known that this fall of water was wholly due to the effect of dynamiting. The water has always left the pond during dry weather, so we would naturally expect the water to fall some in that time.

About the middle of June Mr. Byler placed some six-inch cement tile a short distance from the dynamited portion of the swamp. About the first of July the entire swamp was planted in corn. On August 29, when it was seen by the writer, the corn was about two feet high. Although the season was very wet, there were no large puddles of water. The tile drained portion of the swamp was the driest. The part dynamited was drier than the part not drained by either method. About fifty yards away, there is another pond, which at that time contained considerable water. It was perhaps two feet deep. Mr. Byler stated that in past years this pond was dry before the pond under experiment. The writer again saw the swamp on October 12, and conditions were practically the same. The part which was tile drained was drier than the part dynamited and both were drier than the part not drained by either method. The pond nearby contained about the same amount of water as it did on August 29. A letter from Mr. Byler, dated March 18, 1913, stated that the results were unchanged, but that the drainage was not thorough enough to produce a good crop of corn during a wet season like that of 1912. This crop of corn is the only crop that has been grown on this land for many years. Several of the neighbors said that they had not seen the pond so dry since the old stone drain ceased to work many years ago.

The results of this experiment might indicate that it is possible under favorable conditions, to drain by dynamiting, although it may not be good as a tile drain, yet it might be of great service where an outlet cannot be obtained for a tile drain.

Experiment No. 4B.

Experiment in Dynamiting a Swamp Belonging to O. J. Brown, R. F. D. No. 4, New Castle, Pennsylvania.

This pond is located at the edge of a woodland. It is thickly covered with trees and underbrush, among which are many huckleberries. For the most part the pond is between one and two feet in depth. In no place is it over two feet nor less than one foot, except near the edge.

In the soil surrounding the pond, from six to fifteen inches below the surface, there is a layer of bog ore from three to six inches thick, but no bog ore was found in the pond. In the pond, the top soil is a black clay loam from twelve to eighteen inches thick, which contains a large amount of decaying vegetable matter. The subsoil is a very fine blue clay which prevents the water from seeping away. About five feet below the surface, the clay apparently ends in quicksand.

On May 14, about fifty charges of forty per cent. dynamite were exploded in the subsoil about twenty feet apart, which included nearly the whole pond. The charges were placed about four and one-half feet below the bottom of the pond, which seemed to be nearly through the clay. From two to three half-pound sticks of dynamite were used in a charge. About one hundred and fifteen sticks were used in the fifty explosions. Often an explosion would throw up water in the holes next to it, which would be about twenty feet away. The clay appeared to be well broken up. Bubbles of gas could often be seen escaping several feet away from the explosion. Some rain fell while the work was being done, so no attempt was made to determine any variation in the depth of the water.

On August 30, the writer saw the pond and it contained considerable water. Mr. Brown stated that it contained about the same amount of water as in other years, that it often became dry during a dry season but that it had not become dry during the summer of 1912 which was a wet summer. On October 15, the writer bored a hole twenty feet deep at the edge of the pond. The clay again appeared at about seven feet below the surface of the ground. The clay was continuous to the bottom of the hole with an occasional mixture of coarse sand, but by far the greater part was clay. How much deeper the clay may be is not known.

The dynamiting had little if any effect on the drainage. This swamp may represent a type of land that is probably impossible to drain by dynamiting, or, if possible to do so, the cost of breaking through a great thickness of an impervious subsoil into a porous substratum would be too great to warrant its use.

Experiment No. 5.

Blasting a Ditch in a Swamp.

This experiment was conducted in a swamp belonging to J. A. Boak, R. F. D. No. 4, Lawrence County, Pennsylvania. This swamp lies in a broad valley and covers several hundred acres of land. The soil is a black muck of great depth. Part of the swamp is covered with underbrush but the part where the ditch was dynamited was covered with grass and weeds. The object of the experiment was to determine whether dynamite could be used to shoot an open ditch that would carry away the water. For this purpose a line of explosions was made with Red Cross sixty per cent. Hercules dynamite. For about twenty-five feet, the holes were eighteen inches apart and three feet deep and each hole was loaded with a half pound stick of dynamite. For seventy-five feet the holes were eighteen inches apart and three feet deep and each hole was loaded with one and one-half sticks of dynamite. For the last ten feet, the holes were twelve inches apart and three feet deep, and each hole was loaded with one stick of dynamite. The ground was so wet and soft that holes for the explosions were easily made with a stick.

The best results were obtained from the shots where one and one-half sticks of dynamite were placed in holes eighteen inches apart and three feet deep. The ditch shot out was fully three and one-half feet deep, eight feet wide, and about one hundred and ten feet long. About eighty cubic yards or more of dirt were thrown out and scattered along the side of the ditch.

The results of this experiment indicate that dynamite is very useful in excavating trenches. It can be done very much more quickly and with much less labor than by the use of any ditching machine. In this swamp, the cost would not be far from eight cents a cubic yard, which is probably not far from what it would cost were a good ditching machine used; since, however, the ground was so wet and soft, that it was hard to walk over without sinking in, it is very likely that dynamiting would cost much less than any other method.

Experiment No. 6.

Dynamite as an Insecticide to Determine the Effect of Dynamite on Insects.

In this experiment forty per cent. dynamite was exploded in ant hills. The experiment was duplicated to verify the results.

Experiment No. 6A.

On June 8, 1912, at State College, Pennsylvania, one-half stick of dynamite was exploded in a hole about two feet deep in the center of an ant hill. After the explosion eight dead ants were found which had been crushed by the explosion. The other ants were soon at work repairing the damage done their home. Two days later, June 10, they were still at work.

Experiment No. 6B.

On June 8, 1912, at State College, Pennsylvania, one-fourth stick of dynamite was exploded in a hole one foot deep in the center of an ant hill. A tight cover was spread over the place immediately after the explosion to keep in the gases. After one hour eleven dead ants were found, but they had been crushed. The cover was replaced and two days later, June 10, the ants were working vigorously.

This experiment indicates that in so far at least as ants are concerned, dynamiting has very little if any value in killing insects.

SUMMARY.

While the results of these experiments cannot be taken as conclusive for all conditions, yet they may indicate that the useful application of dynamite as a soil improver is limited. Its usefulness may depend largely upon local conditions. No definite benefits were derived from its use in either orchard or field crops. What it might do under different conditions, or over longer periods is yet to be determined. One pond was drained and the other was not. Its usefulness in shooting an open ditch, blasting boulders and blowing stumps, cannot be questioned. It may be very useful in draining land where no outlet can be found for a tile drain. How permanent its effect may be is not known. As to destroying insects it has not proved to be of any use. It is probably safe to conclude that the application of dynamite as a soil improver is greatly limited, and that it would always be advisable to try it out in a small way before investing much money in its use.

Blasting Boulders and Blowing Stumps with Dynamite.

On April 24 and 25, 1913, A. B. Burkholder, a demonstrator for the E. I. du Pont de Nemours Powder Company gave a demonstration on The Pennsylvania State College Farm in blasting boulders with dynamite. Notes were taken by the writer and the work was photographed whenever possible.

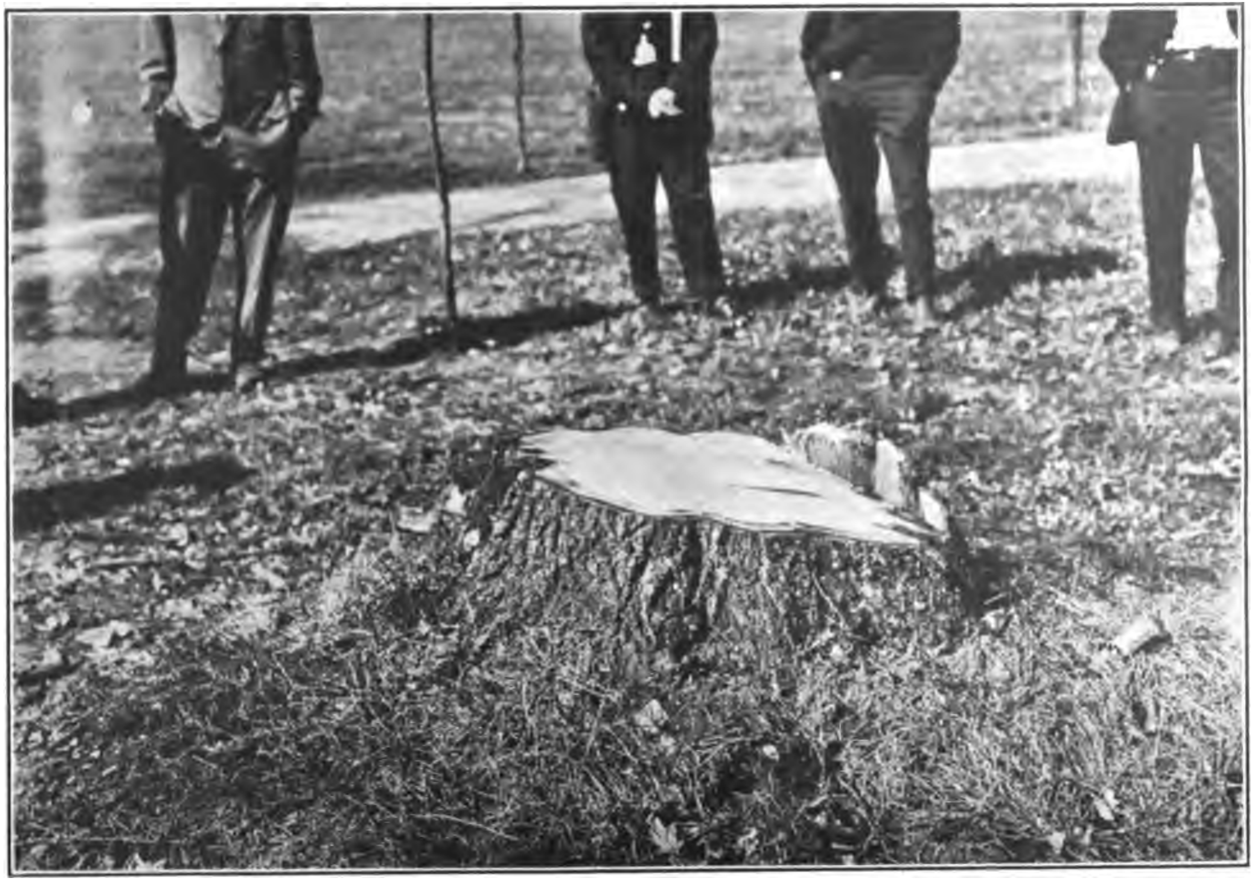
Blasting Boulders.

The best results are obtained in blasting boulders from a quick acting dynamite. Hercules sixty per cent. dynamite is often used for this purpose. The charge should be placed on the spot where the stone would be struck with a sledge if it were small enough to break by sledging. The size of charge required varies greatly with different boulders. The character of the stone, its shape, whether it is above ground or how it may be buried in the ground, and how the charge is placed, must all be taken into account. The only way to determine the amount of explosive required is by judgment developed through experience. Fear of a shower of spalls prevented photographs being taken of this part of the work.

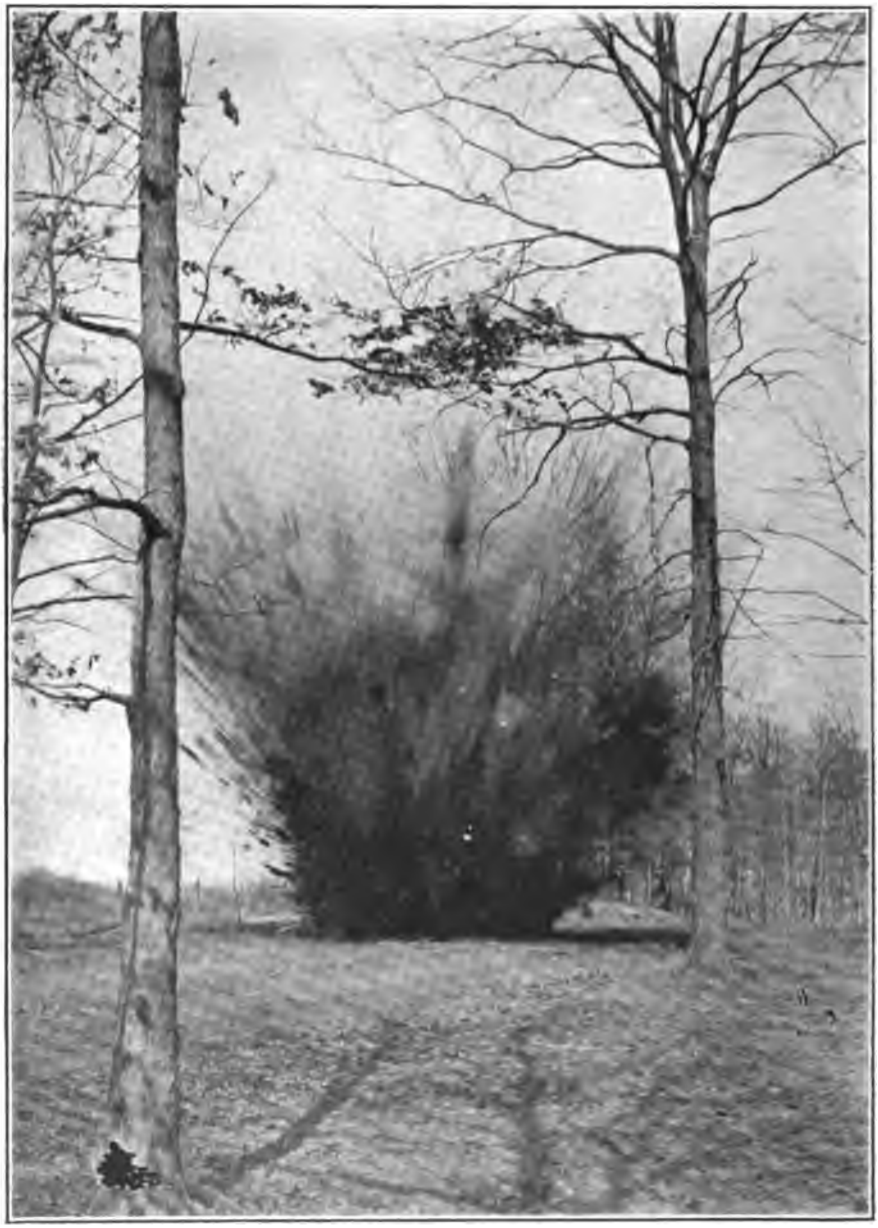
There are several ways of placing a charge to break a boulder. The most common method is called "Mudcapping." By this method it is done by removing the dynamite from the paper, placing it on the stone in a solid mass with a cap crimped on a fuse in the center and and by covering the charge with several inches of damp clay. "Snakeholing" is placing the dynamite in a hole that is made beneath the stone. By this method the stone is not only broken, but is thrown out of its bed. "Blockholing" is a method in which the dynamite is placed in a hole drilled in the stone. In this method less dynamite is used, but more labor is required than in either of the other methods.

Blowing Stumps.

Blowing stumps can be learned only by experience. So much depends on local conditions that almost everything depends on the judgment of the operator. In determining the size of charge and how it should be placed, he must consider the size of the stump, whether it is green or partly decayed, the character of the soil and subsoil, and whether the ground is wet or dry. To use the smallest amount of dynamite he should so place the charge that the spot offering the

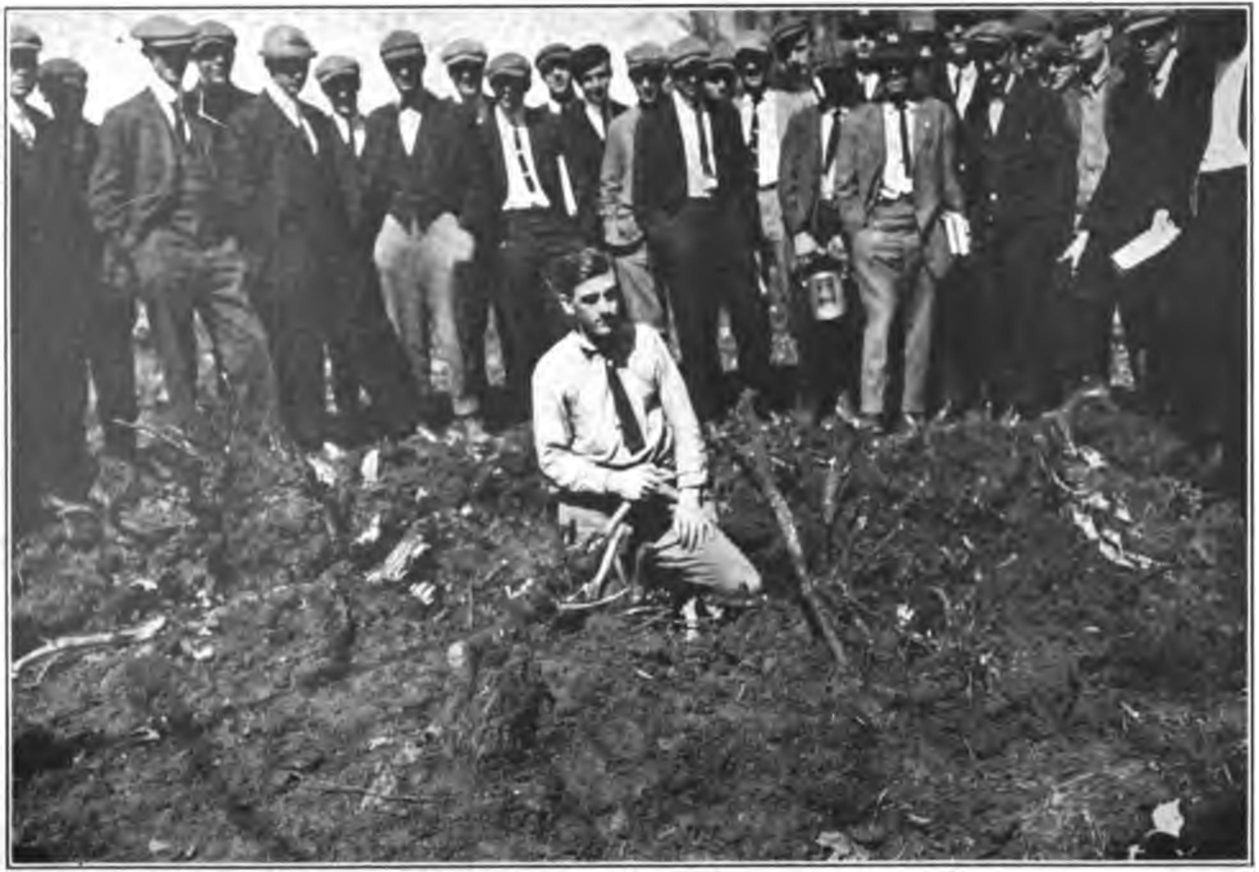


A Green Black-Oak Stump, Three Feet, Two Inches, in Diameter.



A green black-oak stump; diameter three feet, two inches; charge, five pounds forty per cent dynamite.

The Ditch after the Explosion.



Appearance of Spot After a Green Black-Oak Stump, Three Feet, Two Inches in Diameter, Had Been Blown Out With Five Pounds of Forty Per Cent. Dynamite.

greatest resistance will be struck the hardest. To do this with some stumps, it may be necessary to bore into the tap root, or, if a very large stump is partly decayed in the center, it may be difficult to properly locate the charge. So much depends on the judgment of the operator to secure the best results at the minimum cost that it is impossible to give directions as to the amount of dynamite required and how to locate the charge.

Blowing out trees is done in the same manner as blowing stumps, but as the tree has more weight a little more dynamite is required to lift it out of the ground than would be necessary for a stump of the same tree.

The following is a photograph of a stump blown out with forty per cent. dynamite on The Pennsylvania State College Farm April 25, 1912.

U.S. DEPARTMENT OF AGRICULTURE
FARMERS' BULLETIN
600
Contribution from the Bureau of Plant Industry, Wm. A. Taylor, Chief.
July 11, 1914.

AN OUTFIT FOR BORING TAPROOTED STUMPS FOR BLASTING.

By Harry Thompson,
Agriculturist, Office of Farm Management.

INTRODUCTION.

In using explosives to blast stumps from the ground in order to prepare it for farming, it is comparatively easy to place the charge under a stump having a semitaproot or a lateral system of rooting by boring or digging a hole in the earth to a point under the center of resistance and deep enough to give the desired effect.[1]

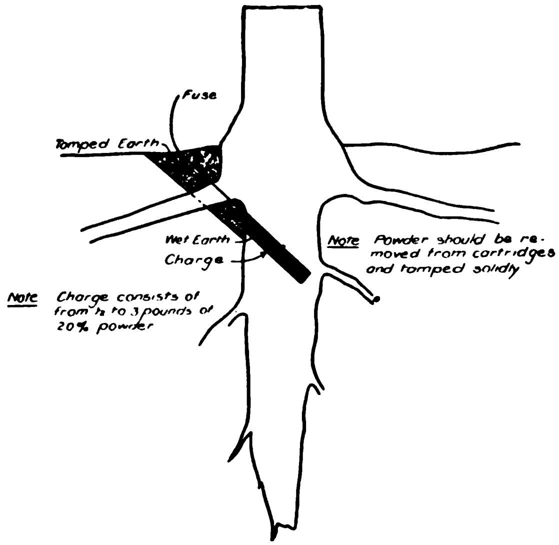

Fuse
Tamped Earth
Wet Earth
Charge
Note Powder should be removed from cartridges and tamped solidly
Note Charge consists of from ½ to 3 pounds of 20% powder

Fig. 1.—Diagram showing a section of a taprooted stump and a charge in position for blasting.

PLACING THE CHARGE.

When clearing land where most of the stumps are taprooted, as in the longleaf-pine regions of the South, it has been found impracticable to place the charge in the earth outside of the stump, as this practice, because of the small size of the lateral roots, usually results in blowing the dirt away from one side and only cracking and slightly loosening the stump.

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[1] For methods of using powder in blasting stumps, see page 14 of "Cost and methods of clearing land in western Washington," by Harry Thompson U. S. Department of Agriculture, Bureau of Plant Industry Bulletin 239, 60 p., 25 fig., 1912.

Note.—This paper gives detailed information concerning a power outfit for boring taprooted stumps for blasting. In those sections of the country where such stumps are abundant it will be of value in reducing the cost of clearing land for agricultural purposes.

45416°—Bull. 600—14

To get the best results when blasting these stumps, the charge must be placed within the taproot. To do this, a hole of sufficient size and deep enough to place the explosive at the center must be bored into the stump. The hole should be bored so deep that the center of the charge will be at or near the center of the taproot. (Fig. 1.)

The hole should be started into the stump from 6 to 10 inches below the surface and should slant downward at an angle of about 45°. When stumps are blasted in this manner most of them will be broken off below the plow line. (Fig. 2.)

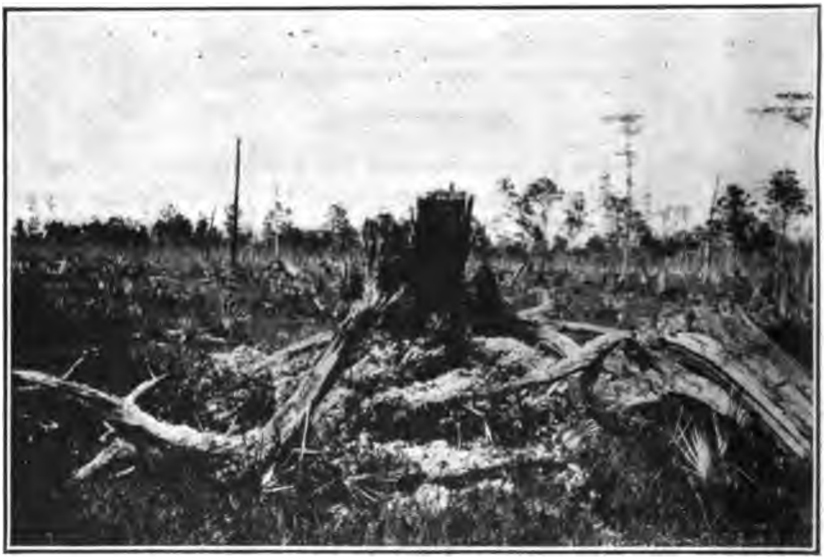

FIG. 2.—Result of blasting a longleaf-pine stump by placing a charge within the stump.

Boring these holes by hand with a 1¼-inch or 1½-inch auger is heavy work and in some cases will require two men when a ship auger is used.

POWER OUTFIT FOR BORING STUMPS.

Several turpentine companies who are using the stumps of the longleaf pine for distillation purposes have assembled outfits for boring these holes by means of electric drills, with power supplied by a dynamo run by a gasoline engine and mounted upon a wagon.

The outfit.—The outfit consists of the following: One 5-horsepower horizontal gasoline engine, one 3-kilowatt dynamo, all mounted on skids or a wagon and drawn by a team (fig. 3); two electric drills using 1½-inch augers of the required length (fig. 4), together with the necessary cables for connecting. Augers 30 inches in length are commonly used, although it is often desirable to drill to a greater depth. For this purpose a supply of augers 4 feet in length is kept on hand. The longer augers break more frequently than the shorter ones.

The crew.—It requires a crew of six to run this boring machine, as follows: An engineer and driver, four drill men (two for each drill), and a cable man or boy.

METHOD OF OPERATING.

After the engine and dynamo have been securely mounted upon skids or a wagon, as shown in figure 3, the outfit is taken to the stump field, the engine is started by the engineer, and the drills are supplied with current from the dynamo. Each drill is operated by two men and can be used on opposite sides of the outfit for a distance of about 100 feet. The cable boy keeps the cables from fouling on the stumps, logs, and underbrush. He also keeps them from kinking, which would cause the copper wires to break.

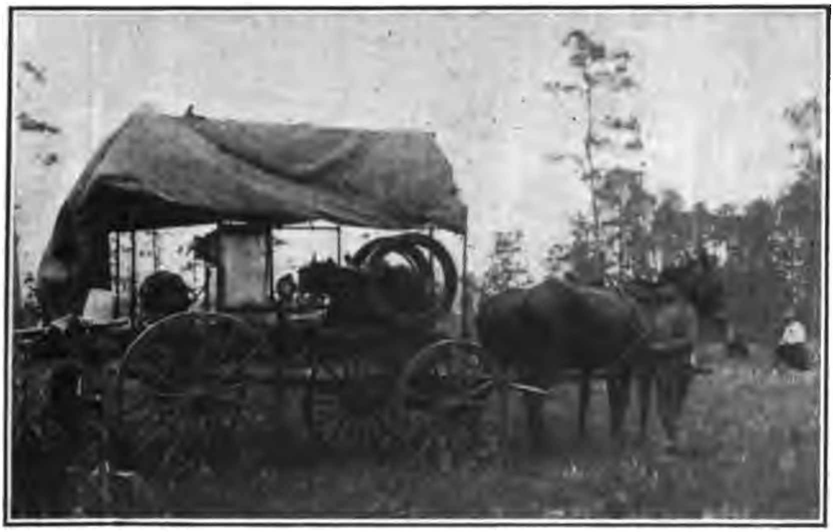

FIG. 3.—Outfit for boring taprooted stumps for blasting.

When the hole is bored to the desired depth (see fig. 4), the drill is removed and a handful of chips put upon the top of the stump to show that it has been bored.

An outfit of this sort drilled 500 stumps a day on an average during the month of May, 1913. The average cost per stump for the holes drilled was slightly less than 3 cents. This cost takes into account repairs, depreciation, and interest, as well as operating expenses.

An outfit of this kind could be utilized for boring the stumps for burning by the method described by Ferris.[1]

Although the companies operating these machines do not usually attempt to blow the stumps from far enough below the ground surface for agricultural purposes, it is estimated that digging away the soil near the stump to permit boring from 6 to 10 inches below the surface will not cost more than 2 cents per stump.

---

[1] Ferris, E. B. Clearing pine lands. Miss. Agr. Exp. Sta. Bull. 159, 12 p., 4 fig., 1912.

RESULTS OBTAINED IN A TEST.

In a test conducted by one of the companies operating a boring outfit similar to the one described, the dirt was thrown away from one side of the stump to a depth of 12 inches and the hole bored into the stump at least 10 inches below the surface. Of the 100 stumps so blasted, 97 were broken off below plow depth. The roots of the remaining 3 stumps were easily cut out low enough to permit cultivation. Slightly less powder was used upon these stumps than where the holes were bored at the surface of the ground. The total average cost for digging, boring, and blasting was 22 cents per stump. This cost does not include the disposal of the stumps, as the tops and roots were used for distillation purposes.

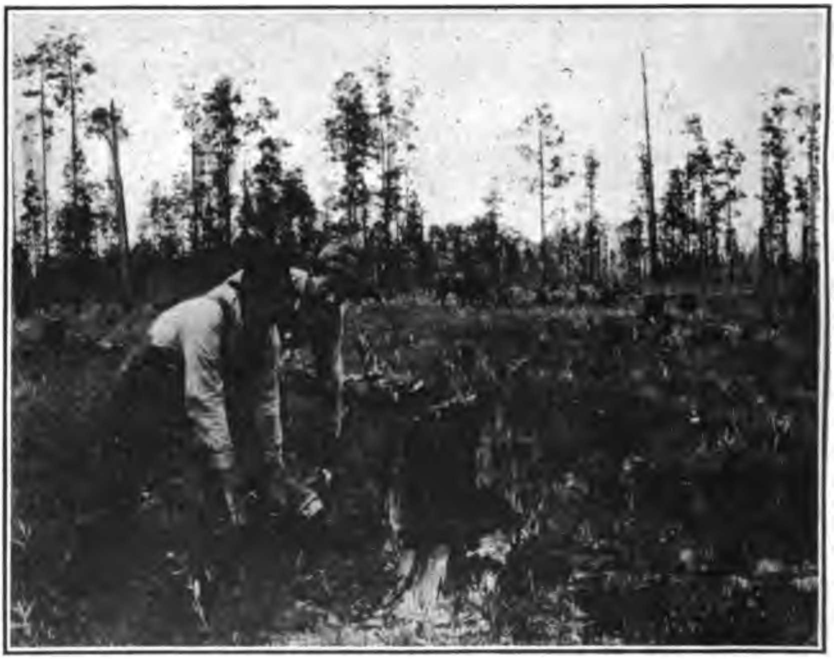

FIG. 4.—Boring a longleaf-pine stump with an electric drill. A 30-inch hole has just been completed.

Average cost per stump for digging, boring, and blasting.

Digging hole	$0.020
Boring stump	.030
Cap and fuse	.025
Powder (using an average charge)	.145
Total	.220

GRADE OF POWDER TO USE.

It has been found by those engaged in blasting the taprooted stumps that the lower grades of nitroglycerin powders are most economical. The higher grades have more of a disruptive effect, tending to shatter the stump, but they do not throw it out of the ground as well as the lower grades of powder. There is very little difference in the effect secured by using 20 per cent and 25 per cent powder. The 20 per cent powder is cheaper and is generally considered the most suitable for stump-blasting purposes.

COST OF THE OUTFIT.

The following prices for an electric stump-boring outfit are f. o. b. distribution point, and freight charges should be added to the place where used.

Necessary equipment for boring stumps, with cost.

5-horsepower gasoline engine	$115
3-kilowatt dynamo	185
2 electric drills	80
6 augers, assorted lengths	25
200 feet of cable	20
Skids	10
Tools	25
Total	460

CONCLUSION.

By using one or more electric boring outfits it is possible in a very short time to bore a large number of stumps for burning or blasting. The number of longleaf-pine stumps per acre that had to be bored in the tests varied from 20 to 70. As an average of about 500 stumps a day can be bored, from 10 to 20 acres can be covered in one day, the maximum number of borings being possible where the stumps are thickest.

The cost of clearing land with this outfit and the use of nitrogycerin powder will range from $5 to $18 per acre, provided the wood from the stumps and roots can be sold for enough to pay for their disposal.

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Better Farming With ATLAS FARM POWDER

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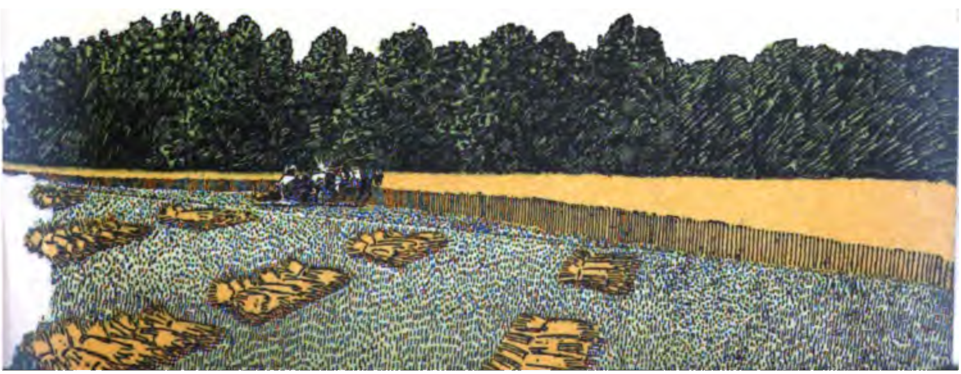

One of the five great Atlas Farm Powder plants.

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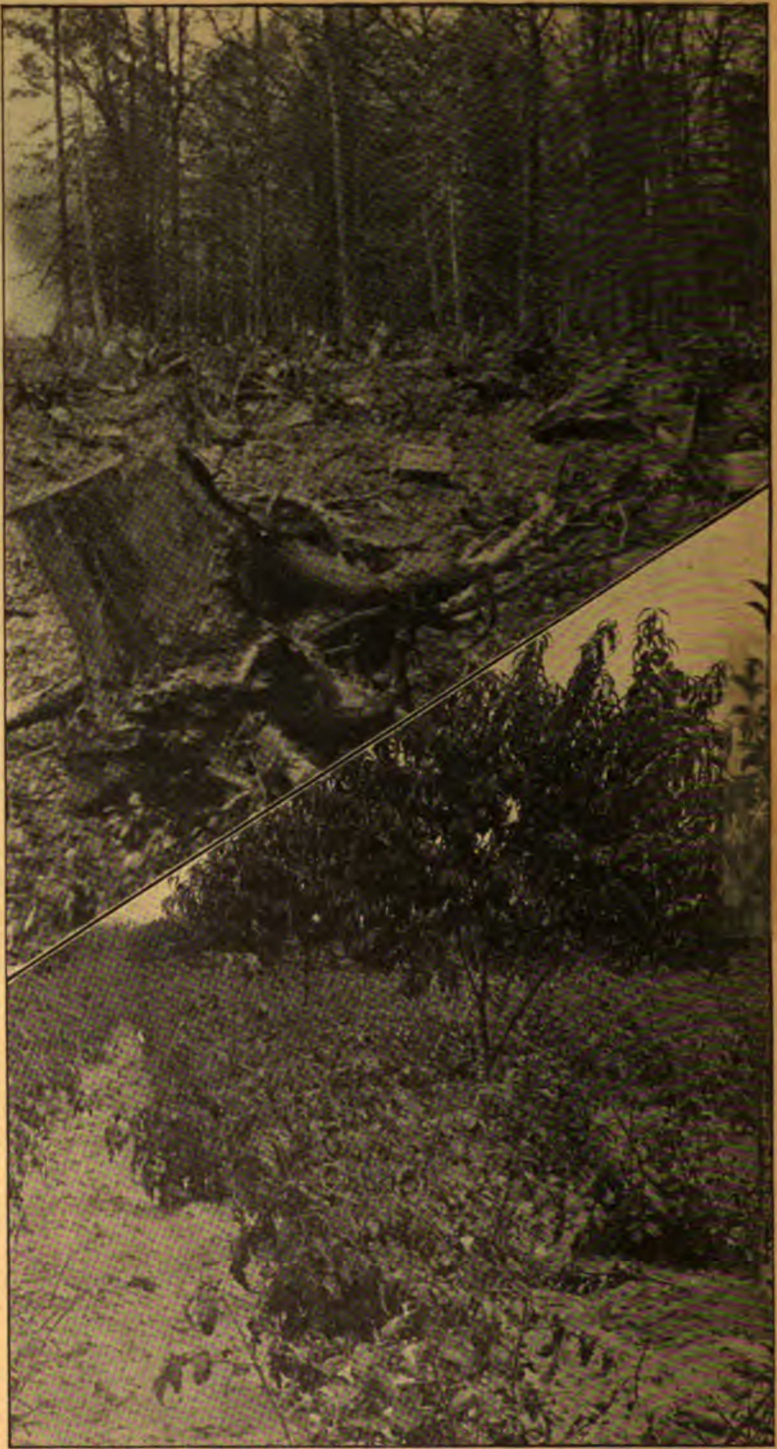


This piece of land was stumpy, rocky and spouty (wet from springs). Atlas Farm Powder transformed it into the garden-like ground in the lower picture, where the tomatoes and peaches are thriving so well.

Atlas Farm Powder is an improved form of dynamite. It is put up in sticks about an inch and a quarter thick and eight inches long. From 98 to 100 of these sticks fill a 50-pound box. This high explosive is made especially to give the best results in blasting soil, stumps, etc. It is the safest explosive adapted to agricultural purposes, and, when properly stored, it retains all its safety and efficiency for years.

In this book we explain why the blasting of the soil is of such great value. We tell why ditching can be done with explosives so much better than in any other way, and how little it costs to remove stumps and stones with explosives. Complete and detailed directions are given for handling the explosive, and for doing all the work.

Atlas Farm Powder is *concentrated energy* that can be used to do many kinds of farm work better than they can be done in any other way. It is a substitute for engines, horses, tools and men. It is always ready. It does the work in a fraction of the time other methods require. Its energy can be used without any waste.

The needs on farms are cheaper power, cheaper plant food, and more abundant water during dry seasons. With present methods there are neither men nor time to do the work required. Atlas Farm Powder rightly used will solve these problems. It is a means to grow bigger, better crops at far lower cost—to keep up and increase the fertility, and to make farm business more prosperous.

Atlas Farm Powder is made at five different plants, located to the best advantage for shipping. It is shipped from magazines in every important centre. This assures low freight rates and prompt delivery.

The Atlas policy is "Safety first," regardless of cost. Only the finest grade of raw materials is used in making Atlas explosives. They are tested at every stage of their manufacture into the Powder by a thoroughly equipped chemical laboratory, and every lot of the Powder is tested when made.

Atlas Farm Powder is sold by dealer's everywhere; your home dealer can take your order. It is easy to buy, easy to use, and inexpensive.

Better Farming with Atlas Farm Powder

CONTENTS

PAGE
The work that explosives will do most quickly, cheaply and better than in any other way.......... 5
Effects of using explosives in cultivation.......... 5
What soil is and how it is used by plants and trees.......... 6
What plant food is and how the roots absorb it.......... 9
Air as a source of plant food.......... 10
How explosives increase growth and yield of all crops..........12, 15, 16
Subsoiling with explosives makes the soil fertile.......... 17
High cost of cultivation reduced by use of Atlas Farm Powder.......... 18
Where explosives have been used..........18, 21, 22, 23
How to prepare charges of Atlas Farm Powder..........24, 27, 28
Benefits of breaking up the subsoil with Atlas Farm Powder..........29, 30
Preventing washing on hillsides and slopes.......... 33
Saving fertilizer by blasting the soil.......... 33
Preparing holes for trees with Atlas Farm Powder.......... 34
Improving old orchards by blasting..........35, 36
Making ditches of all sizes with Atlas Farm Powder..........39, 40, 41, 42
Draining swamps and ponds.......... 42
How to blast stumps with Atlas Farm Powder..........45, 46, 47, 48, 51
Breaking boulders and stone.......... 52
Quarrying.......... 53
Digging post holes with Atlas Farm Powder.......... 54
Excavating for foundations and cellars.......... 54
Road making with explosives.......... 54
Breaking ice gorges.......... 57
A quick way to kill groundhogs.......... 57
Loosening logs, etc., with explosives.......... 57
What Atlas Farm Powder is and why it is superior.......... 58
Handling Atlas Farm Powder and Atlas Blasting Supplies.......... 59
Treatment for freezing and chilling.......... 59
Tools useful in farm blasting.......... 60
Atlas blasting materials, made especially for the farm.......... 63
How to have blasting done by professional blasters.......... 64
Men wanted to learn blasting.......... 64
How to get additional information.......... 64

INDEX

PAGE

ATLAS BLASTING MATERIALS—
  Blasting caps.......... 63
  Electric blasting machines.......... 60
  Electric fuzes.......... 63
  Farm Powder.......... 63
  Illustrations of..........61, 62

ATLAS FARM POWDER—
  Storing and handling.......... 59
  Treatment for chilling.......... 59
  What it is..........3, 58
  Why it is superior.......... 58
  Illustrations of.......... 62

BOULDER BLASTING—
  Charges required for.......... 52
  Effects of, illustration.......... 55
  Proper placing of charges illustrated... 50
  Three ways of doing it.......... 52

CHARGES—
  How to prepare for all kinds of blasting. 24
  Illustrations of each step in priming... 25

DITCHING AND DRAINING—
  Charges required for.......... 40
    —placing of, diagram.......... 43
  Cost of blasted ditches.......... 40
  Directions for blasting.......... 39
  Draining swamps and ponds.......... 42
  Illustrations of..........38, 43, 44

EXCAVATING—
  For cellars and foundations.......... 54

GRADING—
  For road making, etc.......... 54

GROUNDHOGS—
  Killing in burrows.......... 57

PAGE

ICE GORGES—
  Breaking with explosives.......... 57
  Illustration of.......... 55

INFORMATION—
  Given on request.......... 64

ORCHARDS—
  Blasting in, illustrated.......... 26
  How to plant.......... 34
  Improving old.......... 35
  Views taken in.......... 31

POST HOLES—
  How to blast.......... 54

SUBSOIL BLASTING—
  Benefits of.......... 29
  Cost per acre.......... 30
  Effects of, illustrations....7, 13, 14, 19, 20
  Directions for.......... 30
  Making holes for, illustration.......... 56
  Placing charge, illustration.......... 8

STUMP BLASTING—
  Charges, size required.......... 47
    —proper placing of..........45, 46
    —placing of, illustrated.44, 49, 55
  Cheapest way to remove stumps...... 51

TOOLS—
  Useful in farm blasting, list of.......... 60
  Illustrations of.......... 61

TREE PLANTING—
  Directions for.......... 34
  Illustrations of.......... 8
  Effect of blasting holes for.......... 34
  Difference between trees planted in spade-dug and blasted holes, illustrations..........26, 32

THE WORK THAT EXPLOSIVES WILL DO IN THE MOST SATISFACTORY WAY

The following kinds of farm work may be done with explosives more quickly, cheaply and better than in any other way:

Subsoiling farm land for all crops.

Preparing beds for young fruit and shade trees.

Making ditches.

Removing and breaking up stumps and trees.

Throwing out and breaking up boulders and ledges of rock.

Making post holes.

Excavating cellars and foundations.

Quarrying rock.

All of these things may be done perfectly with Atlas Farm Powder or Atlas Powder, which have advantages over any other explosives for these purposes.

Thorough consideration is given to each of these uses in this book. We tell why the work should be done, what its results are, give its cost and its profit, and explain fully the methods of using explosives to accomplish the various purposes. Subsoiling and orchard work are so far-reaching in effects and so great in value that they will be taken up first.

EXPLOSIVES USED IN CULTIVATION

If you explode a proper charge of Atlas Farm Powder in the right place in your soil, the effect on plants or trees is to produce much heavier growth and larger yields of grain or fruit than you otherwise would get. There are thousands of examples of this. The facts cannot be doubted. A few typical examples are cited here.

In Kansas last summer a field of corn that was subsoiled with Atlas Farm Powder grew big and green right through twelve weeks of rainless weather while other corn around it wilted and failed to develop.

In New Jersey, peach trees planted in beds prepared for them with explosives made an average growth of 1378 inches of limbs last season, while other peach trees alongside of them, planted at the same time in ordinary holes, grew only 555 inches. Apple trees planted in blasted holes at the same place developed root systems four times as large as those of apple trees set near them in holes that were dug by hand.

A wheat field in Pennsylvania was subsoiled with Atlas Farm Powder and it grew plants that were five feet high and yielded forty bushels an acre. Other wheat beside it yielded only eighteen bushels an acre. Two parts of an oat field on the same farm showed differences of more than twenty bushels in the yields, the increased productiveness being due to subsoiling. A subsoiled cotton field in Oklahoma yielded 1775 pounds to the acre, against less than half that yield for a field not subsoiled.

The action of explosives in the soil caused these increases of growth and yield. The absence of similar increases in unsubsoiled land adjoining, that otherwise had exactly the same treatment, proves that to be true. But what were the conditions that the blasting brought about? What processes occurred in the soil to make the roots in blasted ground feed the plants so much more abundantly and certainly than they did elsewhere? Did the blasting supply plant food? Or did it just give roots better chances to use food already there? Did the blasts change the structure or the texture of the soil? These questions must be answered if you are to judge intelligently how much money the use of explosives will make for you on your farm or in your orchard.

WHAT SOIL IS AND HOW IT IS USED BY PLANTS AND TREES

The growth of plants or trees comes from just four sources—the ground, the air, the sun and water. Before plants or trees ever began to grow on this earth there was no loose ground or soil at all. The earth was rock. That is, it was minerals bound together solidly. Our present-day rocks usually are composed of such minerals as lime or silica or glass (glass sand). These are minerals as truly as iron or coal.

As the winters and summers passed, water began to wear away and dissolve the softer minerals in the rock. After a time there appeared mosses and rock plants which sent their roots into the crevices the water had worn out and helped to wear the soft rock deeper and to split it apart. When these plants died they gave off acids which helped the water greatly to dissolve more rock and to dissolve it faster.

Frost, and heat from the sun, hastened the processes until the softer minerals were carried out from among the harder ones. What was left was the caved-in remainder of minerals that resisted the water and heat and cold, and became mixed with the remains of plants that grew and died. This is soil. The differences in the kinds of soil are due to the different minerals which formed the original solid rock. Some of them had coarse particles and made sandy soil. Others had fine particles and made loam and clay.

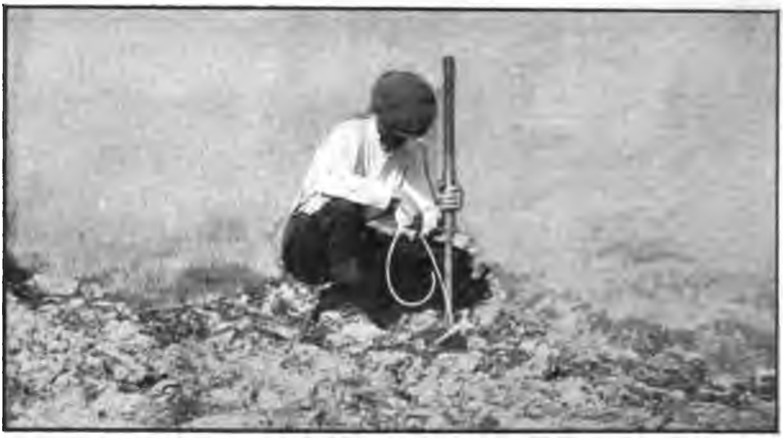
The difference between top-soil and subsoil is only a difference in the stage of decomposition or disintegration of the mineral particles and of the amount of the remains of plants, or organic matter, which is mixed with the mineral particles. Ground near the surface has been exposed to the action of heat and cold and water and plants, and has been changed more than the ground under the surface.

Plants use soil in three ways. They anchor themselves in it so their roots can go in search of food in the ground and their leaves can go in search of food in the air. They consume the mineral elements which compose the soil. They use the soil as a "table" on which to consume food supplied from elsewhere—that is, as a carrier of plant food secured from outside of the ground.

The broken earth in the foreground has been subsoiled with Atlas Farm Powder, and the men are blasting on across the field. The work takes little time.

This picture and the one below show two parts of same field on farm of L. J. Zug, Lebanon, Pa., soil identical. This part produced only half as much grain as the other.

The only difference in the treatment of this field and the one above was that this part was subsoiled with Atlas Farm Powder and the other was not.



Placing a subsoiling charge of Atlas Farm Powder. Note the half stick of Atlas Farm Powder at the end of the white fuse.

After you blast the beds of trees or subsoil the orchard ground, you need nothing but a shovel to make the tree holes, though a furrow as shown may save time.

The splendid condition of this orchard can be attributed directly to subsoiling with an explosive.

WHAT PLANT FOOD IS AND HOW THE ROOTS ABSORB IT

Plants consume about twenty different elements, counting water as one. All but four of these are used in very small quantities and are found everywhere, so they may be ignored in this analysis, just as they may be ignored by farmers and fruit growers. Every foot deep of soil over an acre contains thousands of pounds of them, and a few ounces is enough to grow a crop. The elements that are used to supply ninety-eight per cent. of the food of all plants and trees are *nitrogen*, *potash*, *phosphorus* and *water*.

Water for our crops comes from rains or from irrigation. Nitrogen originally comes from the air. As soils now are, they contain some nitrogen. This was put into them by plants which died and became part of the soil. Potash and phosphorus come entirely from the ground—from the original minerals. Every bit of soil of every farm contains enough of these plant food elements to supply all the plants that could grow in it for a thousand years. The ground for twenty feet or more deep is composed largely of plant food. The reason plants cannot use it is because it never has been broken down entirely. The agencies which transform the minerals into available plant food have not had a chance to act.

Most domestic plants cannot stand water over the roots, but must have all the water they need in the ground near the roots. Surplus water must drain away immediately. The storage in the ground of just enough water and not too much, within reach of the roots, is made possible by a force called capillarity. In its action this force is not unlike the attraction of a magnet. It makes a drop of water follow down the lower edge of a slanting board rather than fall straight down, and it makes oil climb up a lamp wick.

In the ground each little particle of soil, or mineral, so small in clay we cannot see them, but easily seen in sand, is surrounded with a film of water that is held to it by capillarity. This film of water is so thin that it is more proper to call it moisture. Roots can take up this moisture, and they prefer their water in just this condition.

Plants and trees use water to build their wood and stalks and leaves (50 to 95 per cent. of their weight is water), and as a carrier of other plant food. Each little film of moisture about a mineral particle in the ground has dissolved some plant food if there is any available, and the roots absorb this by taking up the water. This water is raised through the roots and stalks. After the food which it carries has been used, the water is given off into the air through the leaves. From 300 to 1500 pounds of water (36 to 180 gallons) are needed to grow one pound of dry matter. Different crops require different quantities, and the soil and weather make a difference. Figured out on an acre basis, an average crop of hay, grain or fruit must have enough water to make a layer six to twenty inches deep.

Roots go to various depths, depending on the condition of the soil and the kind of plant. If the soil is as loose and fine as it should be, the roots of grain plants will go down four to six feet;

grasses, except alfalfa, five feet; alfalfa twenty feet or more; potatoes three feet; apple trees ten feet; peach trees eight feet. If the soil is not loose, the roots may be confined to the first twelve inches of ground. Within whatever depth of ground the roots occupy must be stored the necessary six to twenty inches of water. If it is not there, the plants cannot possibly make full growth. The problem is to put the soil in such a condition that each little particle of mineral matter will be surrounded by its film of moisture, and to conserve this moisture so that it will not be driven off by the pressure of other mineral particles or drawn off by the air or sun.

Water also aids in making available for plants the foods secured from the air and from minerals. One way it does this is to dissolve the softer minerals directly, as has been described. The other is by aiding the growth and activities of bacteria, and, by combining with air, to decompose stubborn minerals.

THE AIR A SOURCE OF PLANT FOOD

All the nitrogen in the world comes from the air. Plants capture it from air through their leaves and through their roots. When the ground is as loose and fine as it should be, the soil contains much air. This air is in contact with the films of moisture about the particles of the soil, and the moisture absorbs nitrogen directly from the air. Another way in which nitrogen reaches the moisture films is from dead wood, stems, leaves, or animal matter. As these are decomposed, the nitrogen which they contain is taken up by the water.

Air and water working together break down mineral plant food elements by oxidation. An example of oxidation is the rusting of iron. Oxidation helps materially to release potash and phosphorus from various minerals. Air and water work together to promote the greatest decomposing and breaking-down process of all—the action of beneficial bacteria.

All of the processes by which the original mineral plant food elements become transformed into available, dissolved plant food have been going on for thousands of years, yet they have succeeded only in breaking down the rock into a softer stage. All except a little of the plant food is still locked up as tightly as ever. As soon as conditions are right, certain small organisms come to the soil. Some of them belong to the plant family, like molds, etc., and others, like bacteria, belong to the animal kingdom.

These low forms of life exist in the soil and consume both the remains of plants and much mineral matter. Bacteria are by far the more important, and we shall confine our remarks to them. One class thrives in the absence of air. This class liberates plant foods to a certain extent, but does it in such a way that the foods are wasted before the roots can take them up. It also actually destroys much plant food. The other class liberates plant food and leaves it in the soil in shape for the crops to use.

When these beneficial bacteria are numerous in the ground, they accomplish more breaking down of insoluble plant food elements in one season than has taken place from other causes for a thousand years. So great is the result of their work that, if they were destroyed, plants could not find enough available food and would starve to death. Plants therefore depend for their existence on the action of bacteria in the ground, and thrive in proportion as the bacteria thrive. The bodies of these bacteria, when they die, fill the soil and are the best of the organic matter, or humus, the necessity for which will be explained later.

The productiveness of the soil, it will be seen, depends little on its kind or type, but almost entirely on the stage of its breaking down from the original rock—on its decomposition into available, soluble plant food. The ground itself is almost all plant food for twenty feet down. The air carries the elements that are not in the ground. Our problem is to make these plant food elements available, so the plants may make use of them.

When we remove a crop we should not aim so much to replace in the soil the food elements it has removed as we should aim to make available the new plant food that never has been disturbed or used since the world began. We can do this far more cheaply and easily than we can supply new plant food from the outside. To do it we have only to bring about conditions required by water and air and heat and bacteria in their transforming action.

Some men who ought to know better figure—on paper—that the only sources of plant food for farms are manure and commercial fertilizer and plants left to rot. To keep up the fertility of land by these means while raising paying crops is a hopeless task. The use of explosives offers a new and better way, which is explained in the following pages.

EVIDENCE

"I have a prosperous growing young orchard which will attest the superiority of trees planted in dynamited holes over those planted otherwise."

J. T. KELLY, Timberville, Va.

"The plants on my subsoiled cotton patch reach up to my neck in most places. So far, by two pickings, I already have taken off nearly 2 bales per acre. This subsoiled patch is far ahead of undynamited cotton. From it I will cut one-third to one-half bale per acre. My 7 acres of sweet potatoes beat anything that is in this country for growth. They were subsoiled, and I am sure of 300 bushels per acre. My alfalfa is fine on dynamited land. I am just about to make the fourth cutting."

ARTHUR WILSON, Crosby, Texas.

"In setting out 2,000 asparagus roots this season, I dug trenches 2½ feet deep and found only about a foot of good topsoil. The remaining depth was a hard clay subsoil. The bottom and the sides of the ditch looked as hard and smooth as a stone wall. The one thing that seemed to be able to conquer this condition was explosives. The results were most satisfactory. The stiff clay was converted into a mellow soil with far less work than it would have taken by any other means."

E. S. BULLOCK, Julian, Pa.

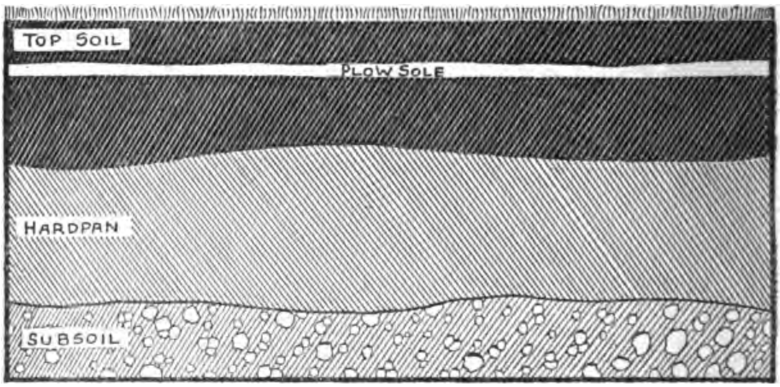
"Holes were prepared for tree planting with dynamite. Experiments in 1905 proved to us that dynamite was the cheapest and most effective method of preparing the soil and opening the soil for the planting of fruit trees. Not only was the earth finely powdered, but the usually compact soil surrounding all spade-dug holes was loosened up and softened and made good soil into which the finest roots could penetrate with ease. Strong root growth in a fine hole was made possible in a very short period of time."

H. B. FULLERTON, Director L. I. R. R. Experiment Station, Medford, N. Y.

HOW EXPLOSIVES INCREASE GROWTH AND YIELDS OF ALL CROPS

The corn, wheat, oats, cotton and fruit which thrived so well on subsoiled land, grew fast and yielded big crops because they had bigger, deeper roots and had more water and more food than crops grown on land prepared in the ordinary way. They grew in soil that had been broken down and decomposed freshly by the action of enough water, air and bacteria.

These agencies released potash and phosphorus that had been locked up in the mineral particles of the soil. They transformed nitrogen that had been insoluble in old roots and leaves. They added new nitrogen from the atmosphere itself. Not an ounce of fertilizer was applied. Not a bit more rain fell on these fields than on others. They were not irrigated. They were not cultivated better than others. The storage of the water, the entrance of the air into the soil, the multiplying of the bacteria, the increased amount of plant food, all were directly caused by just one thing—the action of the explosive.



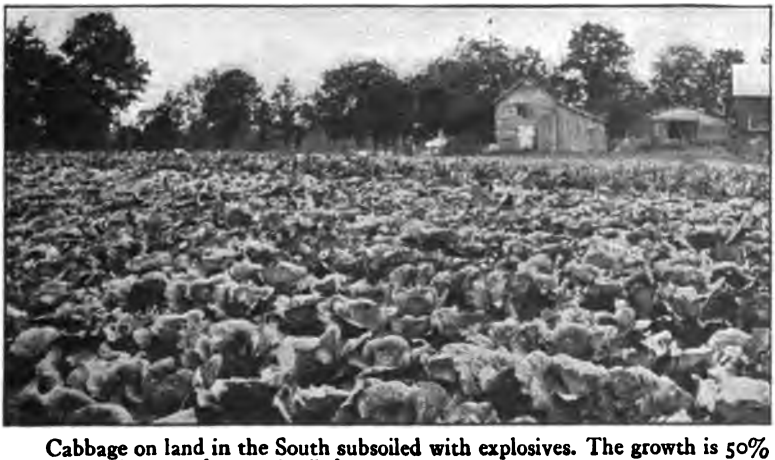
You cannot grow heavy crops over a plow-sole. Unless such land is blasted, the roots are confined entirely above the plow-sole. When it is broken up by blasting, roots can go many feet deep.

When a proper explosive such as Atlas Farm Powder is set off in the ground the expanding gases first tend to lift a layer of soil. Then, as cracks form at the sides, the gases begin to seek their way to liberty through every little crevice and between the soil particles. They powder any lumps of soil they strike, and slide the particles of soil among each other. All of the air is driven out of the ground. The instant that the pressure becomes exhausted new air rushes back into the loosened and pulverized soil.

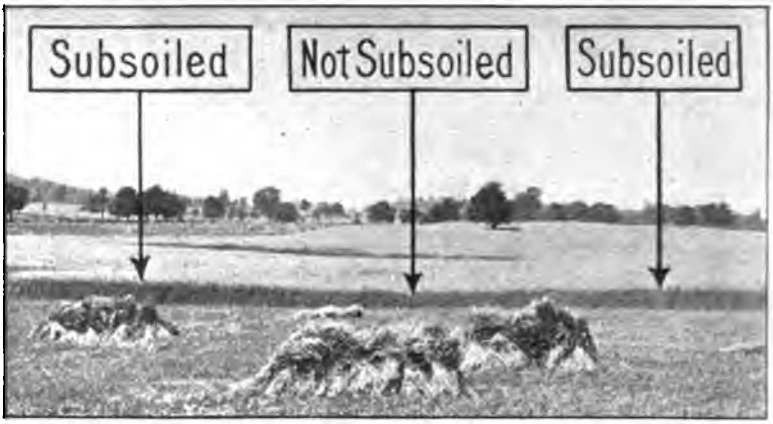
The first result is to bring thousands of pounds of new nitrogen into the soil from the atmosphere. Not only is the top six inches or so of the ground filled with it, but it is sucked down into the ground by the vacuum caused by the sudden end to the press-

This cotton field, owned by Lee L. Galt, Ardmore, Okla., was subsoiled with explosives. It yielded 1775 pounds of seed cotton to the acre.

This field was not subsoiled with explosives. It has the same soil as the one above, and yielded only 624 pounds to the acre.



Cabbage on land in the South subsoiled with explosives. The growth is 50% better than in ground not subsoiled.



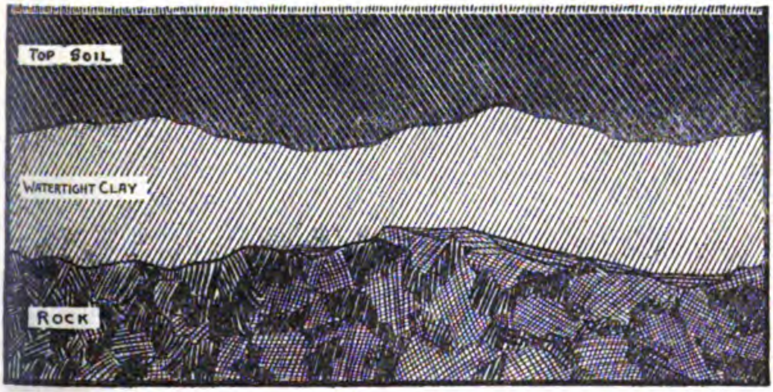
The ground at the sides of the field was subsoiled with Atlas Farm Powder. The centre of the field was not subsoiled. The grain on the subsoiled ground is taller, denser, and better. Photographed on farm of L. J. Zug, Lebanon, Pa.

Oats respond greatly to subsoiling with explosives. On blasted ground the straw grows a foot taller and the yield is ten to twenty bushels an acre more.

All hay and forage crops, especially timothy and alfalfa, respond wonderfully to subsoiling with Atlas Farm Powder.

ure from the gases. If the explosion sends gases six feet deep, the inrush of new air goes just as deep. This nitrogen is available for plants just as soon as the moisture can absorb it.

But this direct supply of nitrogen is only the beginning of the total increase of that most vital and expensive plant food. Roots immediately begin a great expansion in the fine, loose ground. One apple tree that was dug up showed a root system extending more than twice as deep and three times as wide as the root system of another tree dug up from unblasted ground. Corn and grass and grain roots make an even greater increase. They fill the soil many feet down.



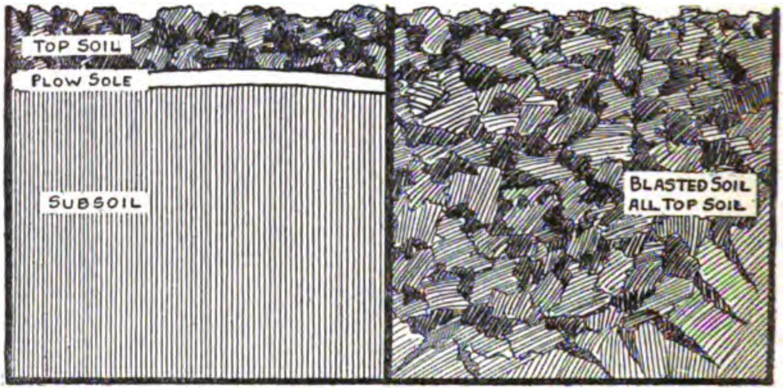
Many soils have a water-tight layer of clay or hardpan within a few inches of the surface. Such soil dries out quickly. When the hardpan is broken up, the ground stores moisture in abundance for many feet down.

Many plants are legumes—plants that gather nitrogen from the air through the leaves and leave it in the soil where their roots grew. Nitrogen forms a goodly proportion of the substance of all roots and stems and leaves. When these roots die after the harvest of the annual crops, their nitrogen is released by chemical and bacterial action. The bodies of the multiplying bacteria provide more organic matter, which in turn is transformed into nitrogen.

Before the blasting, rain water runs off the surface of the unplowed ground in streams. When the ground is plowed, rain soon soaks the six inches of loose top-soil, and then washes the surface badly. Presently it begins to creep out at the level of the plow-sole, carrying into the ditches much available plant food.

After the blasting, the rain water promptly sinks deep into the ground. The explosions, loosening the soil for several feet down, separate the particles so that each one promptly wraps itself in its film of moisture. In filtering down through several feet of ground the surplus water is freed of the plant food which it is carrying away, yet the excess water itself drains off quickly. There now is no water-tight plow-sole or hardpan or layer of clay to hold this excess water.

With the soil particles surrounded by moisture, the several feet of loose ground hold more than the six to twenty inches of water required to grow crops. The water is stored so it cannot escape in dry weather if the surface of the ground is shaded or cultivated. Roots can get it just as they want it because it is in the form of moisture films, and because they can penetrate so easily all through the fine, loose soil.



The panel at the left shows the condition of the great majority of farms where no subsoiling has been done. The panel at the right shows this same land after it has been broken up to a depth of three or four feet with Atlas Farm Powder.

This excellent supply of moisture is just what the bacteria need to thrive and increase. They begin to work on the insoluble mineral plant food elements; and, helped by the dissolving action of water and the oxidating action of the air, they release enormous quantities of potash and phosphorous which have been locked up since the beginning of time. What organic matter there is in the ground before blasting is broken down immediately by the combined action of bacteria and water and air, and its food is made available as the roots require it.

In response to the abundance of water and food, plants immediately take on new life, make heavy growth and fill the ground with roots. All this in a short time means new organic matter, more bacterial and more chemical action, more new nitrogen from the air, and additional potash and phosphorus from the mineral soil elements. The bodies of the bacteria and the roots supply enormous quantities of organic matter or humus. Before blasting there is poorer growth because of a scarcity of plant food and water, and there is a scarcity of these things because of poorer plant growth. After blasting there is heavy plant growth because of abundant food and water, and the abundance of these things is kept up by the heavy growth of plants.

EVIDENCE

"It is easy to observe from the cotton where I dynamited. The cotton grown on dynamited land has made 1775 pounds of seed cotton to the acre, and some yet to be gathered. The cotton raised on the same quality of land adjoining has made a yield of only 624 pounds to the acre. The stalks on the dynamited land are one-third taller, and the bolls are better developed and much larger. The dynamited ground had plenty of moisture all season, but the ground not dynamited, though it received the same cultivation as the dynamited ground, threw off its forms in August." LEE L. GALT, Ardmore, Okla.

SUBSOILING WITH EXPLOSIVES MAKES THE SOIL FERTILE

This is what takes place when you properly subsoil and with Atlas Farm Powder. Not all land is affected to the same extent, but one thing is sure—cultivation with explosives produces the results described and makes plants and trees grow and yield.

If a proper rotation of crops is grown on the land, keeping the soil full of roots down deep, the condition brought about by blasting will be maintained for many years. The dead roots expand and contract as moisture fills or leaves them, loosening the soil particles about them and shifting them past one another. Heat and cold also expand and contract both the organic matter and the soil particles, with the same results. Water follows the channels that roots make up and down and about through the soil, ebbing and flowing freely, keeping moisture in all parts of the soil and keeping the ground loose. Capillary attraction draws moisture from many feet deep whenever a rainless period causes roots to use all of the moisture near the surface.

The quantity of plant food in the soil is increased immediately by blasting, but the greatest results come in the seasons following. Air and water and roots and bacteria proceed to break down the soil for several feet deep, just as the top soil has been mellowed. The ground tends to become richer all the time when it has proper after-treatment. In a few seasons a sample of soil taken from a depth of three or four feet ought to show almost as much free plant food, and just as much water and air and bacteria as a sample taken near the surface.

There is an unlimited supply of nitrogen in the atmosphere, and an unlimited supply of phosphorus and potash in the ground. Do not be afraid you will use it all. When the crops you grow consume the entire layer of soil you now use, there is more just as good beneath, that you may have for the taking. Probably it will be wise to repeat the blasting every five or six years to maintain the good condition in perfect working order.

If you could take up all your ground for six feet deep and mix it dry, as concrete or mortar is mixed wet, you might produce better results than explosives give. But no less thorough handling of the soil would equal the results of blasting. Subsoiling with machines cannot be compared to it. The most intensive cultivation with tools looks puny beside the work done with explosives.

It is necessary to keep the surface of the ground cultivated during dry weather to prevent the escape of moisture, and it is necessary to keep down weeds. Plowing and harrowing must be done when explosives are used just about the same as before.

But these old methods used alone are failures because they do not produce enough results or produce them fast enough. Commercial fertilizers are too costly to permit many farmers to use them as the main source of potash and phosphorus. Manure and cover crops cannot keep up the nitrogen supply as they should unless the ground is loosened deeply and transformed so roots find themselves at home four feet deep.

THE HIGH COST OF CULTIVATION REDUCED BY EXPLOSIVES

During the last twenty years the rate of nearly all wages has advanced fifty to one hundred per cent. It used to be possible to hire good farm hands for $1 a day. Now they must be paid $1.50 to $2.00. During this same time the cost of horses and machinery has gone up greatly. Land values have increased, taxes have increased. Crops are no larger than they were before, and market prices of farm products have not increased in proportion.

Farmers must find some way to lower this cost of production and to increase the income from their crops. New methods of doing the work are needed—methods that demand fewer men and less work, and that are more effective in supplying plant food and in keeping up fertility. On the solution of such problems depends the success or failure of the business of many farms. Only by using new methods can living profits be made, or farm prosperity be assured.

The proper and continued use of Atlas Farm Powder for subsoiling and ditching will enable the farmer to do his work with fewer men, in shorter time. It will enable him to obtain plant food cheaply. It will increase his crops while lowering their cost.

WHERE EXPLOSIVES HAVE BEEN USED

In 1912 and 1913 more than a million fruit trees were planted in holes blasted with explosives. During these same two years many thousands of acres of land intended for general farm crops of grain, cotton, hay and vegetables were subsoiled with dynamite. Hundreds of miles of ditch were dug, and many swamp areas were drained with explosives.

We give here the names of a few people and firms whose operations are reported as this book is written.

The United States Government, in Bulletin 38 of the Hawaii Agricultural Experiment Station, reports the results of experiments in subsoiling covering three years. This station found that explosives were of the greatest value in securing the proper amount of moisture and aeration in soil and loosening the ground so that the roots could penetrate it. The tests covered all kinds of fruit trees grown commercially and were so successful that the station confidently recommends the use of explosives as the best method of preparing soil for trees.

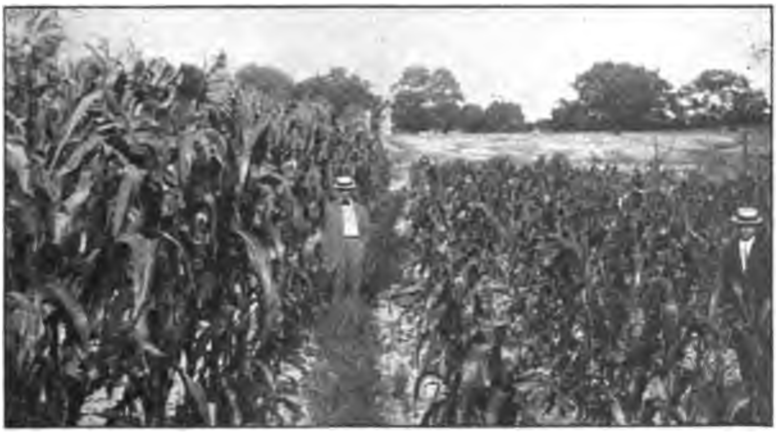
In Tennessee, corn grown on land subsoiled with an explosive made more than twice the growth of corn grown on adjoining land not subsoiled. This corn field is illustrated on page 19. The experimenters give explosives their whole-hearted endorsement.

The Oklahoma Experiment Station has blasted the subsoil in young orchard plantings where hardpan and rocky ledges occurred beneath the soil. It reports that the work promises good returns.

The blasting of soil was first carried on extensively in Kansas. Former Governor Crawford took an active interest in this work, and a great many representative men throughout the state

This field was subsoiled with Atlas Farm Powder before it was planted. The potatoes made a remarkable growth and yielded 210 bushels to the acre.

These high-grade potatoes were grown in the field shown above on land that was classed as "abandoned" before it was cultivated with explosives. Photographs from Pennsylvania Railroad Demonstration Farm, H. F. Lippincott, Agriculturist, Commercial Trust Building, Philadelphia.



The corn growing at the left, at Clarksville, Tenn., was subsoiled with explosives and that at the right was not subsoiled.

Strawberries between young orchard trees growing luxuriantly on ground subsoiled with explosives.

Intensive farming methods in fruit and vegetable growing are not efficient or complete unless the ground is subsoiled with Atlas Farm Powder.

Plants thrive wonderfully when the soil is worked over with Atlas Farm Powder, because the roots penetrate into the soil so deeply.

have used dynamite. At this time dynamiting has become almost as well established a practice on farms of many parts of Kansas as plowing has. It is a statewide custom, just as commonly seen and just as important there as harrowing is on the eastern shore of Maryland, or as the use of disc plows and harrows in Northwestern grain fields. Few orchards are planted without blasting the tree holes. In Nebraska the same holds true. Farms generally throughout the southern and eastern part of the state are using explosives for subsoiling.

The Ohio Agricultural Experiment Station, of Wooster, reports satisfactory results in blasting very hard or stony land for planting orchard trees.

The Pennsylvania State College and Experiment Station has conducted a number of tests, using dynamite successfully in orchards and in fields.

One of the largest users of explosives is J. H. Hale, the peach and apple king of Connecticut and Georgia. He has used thousands of pounds of explosives, and has set twenty to thirty thousand trees in blasted holes.

The Long Island Railroad Experiment Farm, at Medford, has used dynamite in all kinds of soil work. It took up raw waste land, cleared it, drained it, and cultivated the soil with explosives.

The Rosecliff Fruit Farm, at Waynesboro, Va., is a large user of explosives. It set all of its trees in blasted holes, and used explosives in the ground around the trees at the ends of the limbs, sometimes exploding six charges around one tree, a half stick in a hole. The results from this treatment have been wonderful yields of fruit possessing improved color, quality, and size.

Stark Bros. Nurseries & Orchards Company, Louisiana, Mo., uses explosives extensively, not only in tree planting, but in blowing stumps, ditches, etc.

J. G. Harrison & Sons Nurseries, at Berlin, Md., have found explosives most useful, and they have used them extensively. Their soil is light and is not packed solidly nor underlaid with hardpan, but they have planted ten orchards of 200 acres each, and have set nearly all of the trees in blasted holes.

The William P. Stark Nurseries, at Stark City, Mo., use explosives regularly in their orchard and nursery work. They have subsoiled the ground in old orchards, and have blasted the subsoil around bearing trees in younger orchards. They find that, when explosives are used, more of the young trees live, make a larger growth, yield larger crops, suffer less from dry weather, and, in their opinion, will live longer.

The Vincennes Nurseries, at Vincennes, Ind., are planting eight acres of pecan and fruit trees as this book is written, and are using dynamite for all of them.

The William H. Moon Co., Glenwood Nurseries, Morrisville, Penna., finds explosives extremely valuable for planting shade trees, hedges, etc.

H. M. Magee, of Waynesboro, Va., has set 2,000 young apple trees in blasted holes, and is enthusiastic about explosives as a means of quick, cheap, and thorough cultivation. His trees planted in blasted holes average 96 per cent. of live trees at the end of the growing season. He has proved conclusively that the blasting of tree holes insures a rapid growth of strong fruit wood, and he says that his trees planted in holes made with explosives bear fruit one year earlier than trees planted the old way.

The Pippin Hill Fruit Farm, at Blairstown, N. J., has planted a lot of trees in blasted holes, and reports that these trees have grown almost twice as much as trees set without the use of explosives.

The Rosemar Orchard Company, at Parkersburg, W. Va., one of the largest orchardists in the state, always blasts holes for fruit trees. At Staunton, Va., in the heart of a famous orchard section, William A. Pratt planted 2,000 trees with results that were "more than satisfactory."

In the Shenandoah Valley, at Timberville, Va., J. T. Kelly has a young orchard which amply attests the superiority of trees planted in blasted holes over those planted in the ordinary way.

In the citrus fruit section of Florida, E. V. Blackman has used great quantities of explosives in preparing holes for orange and grapefruit trees. He began the use of explosives for this purpose many years ago. The blasting of holes for trees has become the custom in that neighborhood since fruit growers and farmers generally have learned what it will do.

At Columbus, Ga., F. W. McMurrain planted pecan trees in blasted holes. These show a marked superiority over other pecan trees nearby, planted by ordinary methods.

In Lebanon County, Penna., L. J. Zug used Atlas Farm Powder in subsoiling his fields. During the last season his oats on subsoiled land have been almost twice as good as those on similar fields not subsoiled with explosives.

At Seaford, Del., in an orchard of more than 200 acres, the ground was prepared for almost all of the trees with explosives. These trees are making a remarkable growth, some of them bearing at 3 years of age.

At Ardmore, Okla., Lee L. Galt subsoiled cotton fields with explosives. The cotton that grew on the blasted land made 1775 pounds of seed cotton per acre, while on unblasted land adjoining, the cotton made only 624 pounds. The stalks on the subsoiled land were one-third taller than the other stalks, and the bolls were better developed and much larger. Dry weather prevailed throughout the summer of 1913, and the ground not subsoiled, though well cultivated, threw off its forms in August. The field which was subsoiled received exactly the same cultivation, but remained moist and green all summer. See the pictures of this cotton on page 13.

At "The Pastures," a large farm operation near Belfast, Maine, managed by Horace Chenery, a mile of ditch has been dug with explosives, a great many fruit trees have been planted, and many boulders have been broken up. This farm continues to buy quantities of explosives from time to time, and would not be without them.

Near New Haven, Conn., George B. Smith cleared an acre and a quarter of land that was worth about $5 an acre before he began. After blasting the stumps and stones, the land was worth $200 an acre. The first crop was winter wheat and it went 40 bushels to the acre.

A similar experience has been noted at Crosby, Texas, where Arthur Wilson subsoiled a cotton field. The cotton growing on this land reached up to his neck and made two bales an acre. Other cotton planted on similar land nearby did well to yield a third to a half bale an acre. Mr. Wilson also blasted the subsoil for a sweet potato field, and no other potatoes in that country equalled his for growth. They yielded 300 bushels an acre. He also has alfalfa growing on subsoiled ground, and it is thriving wonderfully.

An interesting account of ditch blasting comes from the Texas Agricultural Experiment Station, at Angleton. "A feature greatly in favor of using dynamite in ditching is the rapidity with which it can be done," the director reports.

In Kansas a man had a forty acre pond with water three feet deep. Twenty-five pounds of dynamite properly placed and exploded in the ground, drained the pond, and in thirty-six hours the water had disappeared.

J. S. Fowler, Anderson, S. C., has been using explosives for years in cotton and corn fields. With the use of dynamite Mr. Fowler secures as high as 200 bushels of corn an acre. He says that no dry weather affects his cotton when it is planted on land subsoiled with an explosive.

The Wyoming Agricultural College Experiment Station at Laramie conducted considerable dynamiting on its farms in the spring of 1913. It planted both fruit trees and shade trees in blasted holes, and regards the work as highly successful.

The New Jersey State Horticultural Experiment Station, at New Brunswick, conducted extensive tests of explosives in planting peach and apple trees. Its soil is mostly red shale loam. At the end of the first season's growth, careful measurements were made of the branches and twigs developed on each tree. Explosives were used in three different orchards located in different places.

In one orchard the total growth of the blasted trees averaged 794 inches, while trees planted in the ordinary way grew only 665 inches. In another orchard blasted trees grew from 1207 inches to 1952 inches per tree, while trees planted in dug holes grew only 560 inches. There also was a slight advantage in the thickness of the trunk in favor of the blasted trees. The far greater growth of the blasted trees could be noted without trouble in just looking over the rows of trees.

From one end of the country to the other come reports of the successful use of explosives in agricultural work. The foregoing were selected at random as this book was prepared. Atlas Farm Powder is adapted perfectly to all agricultural purposes and is used on thousands of farms.

Twentieth century tillers of the soil who are going to eat enough and live comfortably and become independent have got to use explosives to make their land produce bigger crops at a lower cost.

HOW TO PREPARE THE CHARGES OF ATLAS FARM POWDER

Charges for all kinds of farm blasting are prepared in the same way. Read and study these directions carefully before you begin the work.

In cold weather examine the Powder to see if it is chilled or frozen. If it is in this condition you must thaw it or warm it before loading, as described on page 59. Atlas Farm Powder seldom needs this attention because it does not freeze or become insensible from chilling until it is very cold—ordinary freezing weather does not affect it. In warm weather the only precaution regarding the condition of the powder is to see that it does not lie in the hot sun unshaded. Too much heat may damage it.

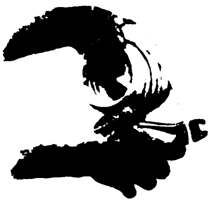
Use only strong caps or electric fuzes. The strength of caps and electric fuzes is indicated by their numbers. No. 6 strength is on sale by most dealers, and does its work well. No. 8 caps are stronger and are worth the slight additional cost. If caps or electric fuzes are kept in a damp place, they may absorb moisture and weaken. Weak caps or electric fuzes will not explode the Powder completely. If Powder is fired with weak caps or electric fuzes, the resulting explosion will be less powerful, and will give off poisonous gases, or the Powder may fail entirely to go off.

The electric fuze is the equivalent of the fuse and blasting cap. It is a copper cap in which are fastened two insulated copper wires. You put them in the stick of Farm Powder just the same as you would put in a blasting cap and fuse.

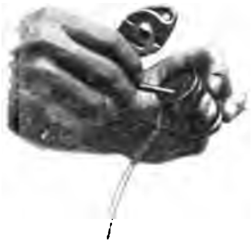
Whether to use common blasting caps or an electric blasting machine and electric fuzes to explode the charge depends on the amount of work and the kind of work you have. If you have only a few charges to put off, or if the charges are to be far apart, then the cap and fuse is the better method. If you have many charges to put off, or if all are to be exploded at once, as in a ditch, the electric blasting machine is better. When charges are to be exploded under water, the electric method is the only one to use. You cannot explode several charges at the same instant in any other way than with a blasting machine.

To prime a stick of Powder proceed in this way. Cut your fuse to the required length. Fuse burns two to three feet a minute. In blasting stumps you should keep 100 yards away and in blasting stones 150 yards away. In subsoiling you can remain within a few yards of the explosion. The fuse must reach to the surface of the ground; otherwise its length is determined by the distance you must run before the explosion takes place.

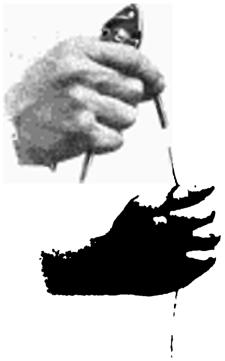
If the fuse is cold, warm it before you unroll it or it may break. Cut the end off square. Be sure that this end is fresh and dry. Then insert it carefully into the blasting cap clear to the bottom. Don't press or twist it against the high explosive in the bottom of the cap. While holding it gently to the bottom, crimp it with a regular crimping tool as close to the open end of the cap as you can. Under no circumstances attempt to crimp a cap with your teeth. In a pinch you may press it with ordinary pliers, but always remember that the lower two-thirds of caps



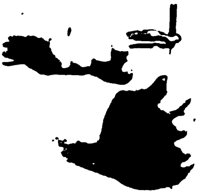
Cutting fuse from roll with cap crimper.



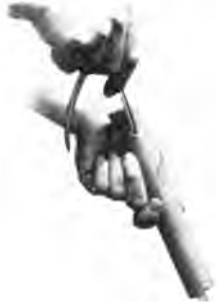
Taking one cap carefully from box.



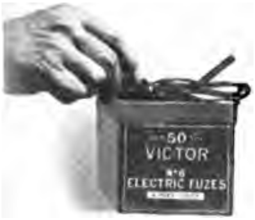
Inserting fresh end of fuse in cap.



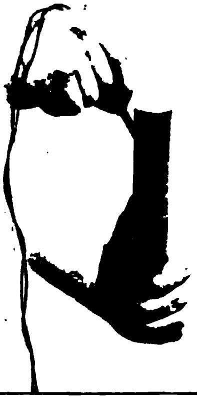
Crimping cap with the cap crimper.



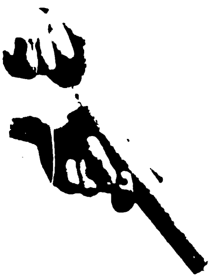
Punching cap hole in stick with cap crimper.



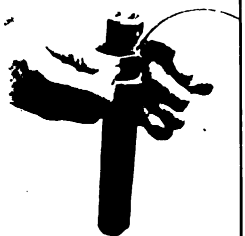
Taking one electric fuze carefully from carton.



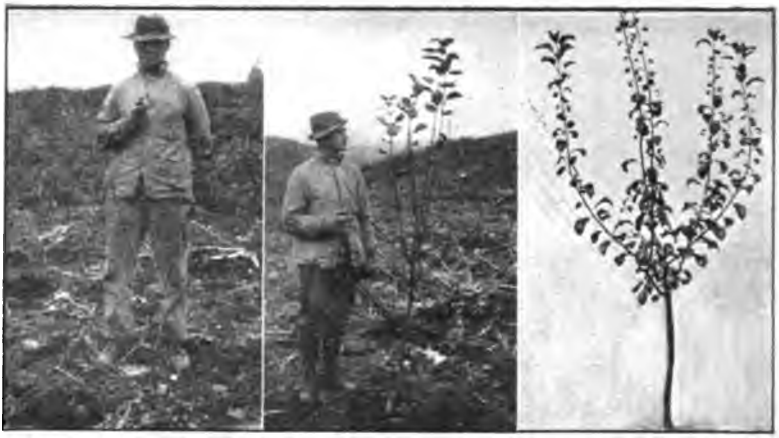
Inserting electric fuze in stick.



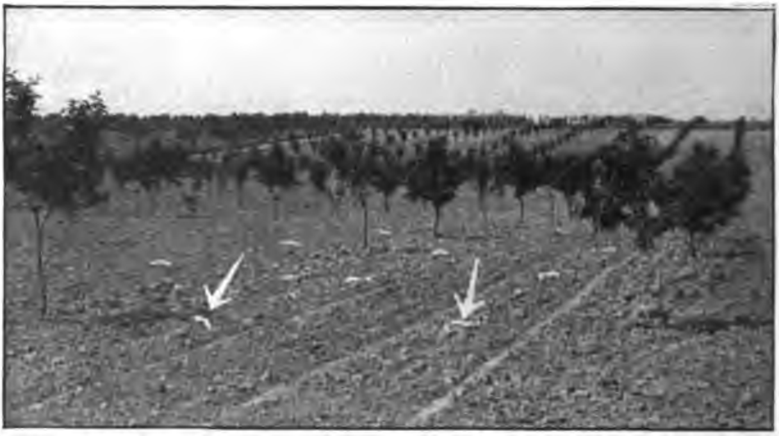
Inserting cap and fuse in cartridge



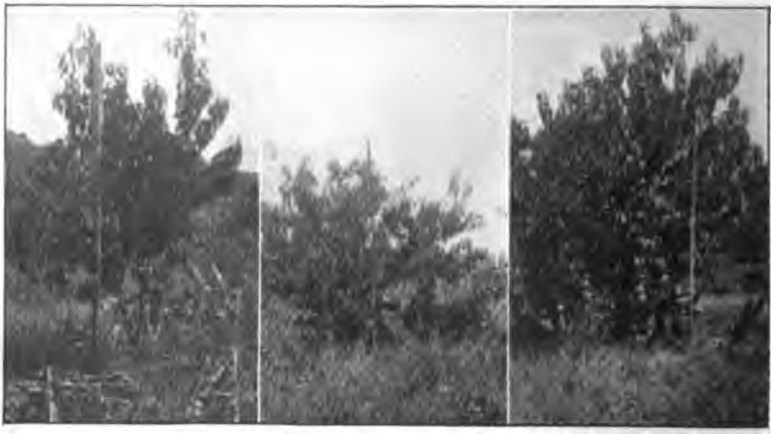
Tying fuse firmly to cartridge with string.



The tree on the left was planted in a spade-dug hole; the trees in the middle and to the right were planted in holes blasted with Atlas Farm Powder.



Young trees not planted in holes blasted with explosive, should be subsoiled in the manner indicated here. Place very light charge within 6 to 8 feet of trees.



At left and centre, two one-year peach trees planted at the same time, one in a blasted hole and the other in a dug hole. At right, two-year peach tree in blasted soil.

is dangerous, and that if a cap goes off in your hands you are likely to lose your hand. Caps must be handled with far greater care than the Farm Powder itself.

With a piece of wood about the size of a lead pencil or with the end of one of the handles of the cap crimper punch a hole into the side of a cartridge of Powder two or three inches from one end. This hole should slant lengthwise into the cartridge as much as possible, and should be just deep enough to bury the cap and about a quarter inch of the fuse or the electric fuze wires.

With the cap in this hole, tie the fuse or the wires to the side of the stick with a string passed around the stick two or three times. Give the string a wrap or turn around the electric fuze wires or fuse. Make the string pretty tight, so the caps will not pull out when you lower it into the hole by the fuse or wires. Side priming is better than end priming because it gives you a chance to put the tamping stick against the end of the cartridge without danger of disturbing the cap. Don't lace the fuse through the cartridge or put it in the lower end and bring it up around, or wrap it around the cartridge. If you do any of these things you are likely to break the fuse or make it set fire to the Powder. If the Powder catches fire it will not explode properly and it will give off noxious fumes.

If the charge consists of more than one stick, put the primed stick or half-stick in last, on top of the rest of the charge. When loading dry holes, slit the paper of the sticks lengthwise in about four different places. When you press these slit cartridges home with the tamping stick, they will swell and fill the holes tightly. In wet holes do not slit the paper. Put the sticks in whole, and tamp and fire the charge as quickly as possible.

Use wood for tamping—never an iron rod. Begin your tamping by rolling down fine earth or sand, and gently pressing this into place. After you have four or five inches of such material on top of the charge, you can begin to put wetter ground or sand in and ram it tighter. Fill the hole up to the surface of the ground and get the tamping material solid. The idea is to hold in the gases by an equal resistance on all sides.

There is an old belief that the force of dynamite is downward rather than upward. This is a foolish idea—there is absolutely nothing in the action of dynamite to justify it. The force of dynamite works in all directions at once. The gases from high explosives get out of their confinement by the easiest way. They act quickly and tear in all directions to find the best way out. Firm tamping is necessary to increase the resistance where you don't want the gases to blow out, in order that they may shatter the stump or stone or ground that you desire to move.

Post holes should not be tamped because in them you want the explosion to loosen the ground for only a few inches around it.

Be sure that each stick of a big charge is in firm contact with the other sticks. When the holes are loaded, see that everybody is beyond range of any flying roots or stones before you light the fuse or connect the blasting machine with the charge.

In case of misfire with a fuse, do not go near the charge for two or three hours. Then, instead of trying to dig out the charge, put down another charge of one stick within a foot of it, and both charges will be exploded by a transmitted shock from the little one.

Electric fuzes must be inserted into the sticks of Powder in exactly the same way as blasting caps and fuse are inserted. Use fuzes with wires long enough to reach well out of the holes. After you have all the charges loaded that you are going to shoot at once, connect the fuze wires together in the way shown in the picture on page 56.

Then connect the outside wires from the two outside charges with leading wires extending to the blasting machine. If fuze wires will not reach each other, use connecting wire such as is illustrated on page 62. When everything is ready see that there are no people or stock within range of the explosion, connect the leading wire to the blasting machine and fire with the machine.

When charges for any purpose are to be placed under water, the end of the caps where the fuse enters, the places in the sticks of Powder where the caps enter them, and the ends of the sticks must be made watertight with tallow. Be careful about this. When you cut sticks in two, coat the open ends with tallow or clay if the charges are to be used in wet places.

EVIDENCE

"My dwarf apple orchard was set 6 years ago in blasted holes. There is no hardpan in my soil, and I am sure that a thriftier lot of trees cannot be found anywhere. They are much stronger and healthier than they would have been if planted under the old conditions."

F. E. DAWLEY, Livingston County, New York.

"I subsoiled a piece of my land in March, 1912. That season it produced 102 bushels of corn to the acre. Previously it had been making 35 to 40 bushels to the acre with the same cultivation and fertilization. In November, 1912, it was sowed to wheat and made 54 bushels to the acre, and immediately the wheat was harvested, the land was planted in corn and made 40 bushels to the acre. If I had time I would subsoil all my land with dynamite in the fall and let the ground hold the winter rains."

A. J. PIRKLE, Buford, Ga.

Here is an instance where a big drainage ditch or canal was excavated with dynamite in a mighty short time, and at comparatively low cost. While the need of such work is not found on many farms, yet there are times when a canal like this should be dug, and would be dug if it were known that it could be done to such good advantage with dynamite.

"The work was a cut 12 feet wide at the bottom, 3 feet deep at sides, 5 feet deep through the centre, and 400 feet long. 500 pounds of Atlas Powder 60% did the work, and the dirt was thrown clear of the ditch, leaving clean, straight bottom where we wanted it."

W. W. KOONSE, Malta Bend, Mo.

"We have been able to accomplish work by the use of explosives which otherwise never could have been done. Other work was done which, if it had not been for explosives, still would be in progress or unstarted. I know that we have made more than a mile of ditch this summer with explosives. For planting apple trees, an explosive is of a great deal of value. It saves men labor in digging holes, in clearing land, and it insures far better results in crops from the land. In blasting boulders we seldom drill, nearly always mudcap. This takes a little more dynamite but saves more than its equivalent in time."

HORACE CHENERY, The Pastures, Belfast, Me.

BENEFITS OF BREAKING UP SUBSOIL WITH ATLAS FARM POWDER

The beneficial effects of breaking up the soil with an explosive have been explained at length in the first pages of this book, but these pages may be glanced over again. Subsoiling with explosives is one of the most important advances ever made in farm methods. Briefly, the effect of subsoiling with an explosive is to give you four to six feet of topsoil in place of the eight to twelve inches that you have now.

The first effect is to loosen the ground so that the surface run-off of water is practically eliminated, because the rain sinks into the ground as fast as it falls. At the same time the water storage capacity of the soil is increased by making the soil fine so that each particle is enabled to hold its film of moisture. Such moisture is held through the driest weather in a condition in which the roots can get it best. The shattering of hardpan and breaking up of heavy clay are simply incidents in the drainage and water storage processes.

With the presence of enough moisture and not too much, bacteria thrive, general decomposition of insoluble mineral plant food is hastened, air is permitted to act on the locked-up plant food in conjunction with moisture, and the total result is that an abundance of plant food is made available.

The following is an extract from a bulletin of the United States Hawaiian Experiment Station:

"Success in farming depends to a large extent upon the maintenance of proper conditions for *aeration* and *drainage*. Otherwise it seems impossible to hold *nitrogen* in the soil *in an available form* or to bring about a suitable regulation of the water supply or of the distribution of air among the soil granules."

If it were added that phosphorus and potash could be made available by processes set in motion by the blasting, the matter would be expressed more clearly. Blasting ground will increase its *net* return 100 per cent. Thousands of progressive farmers have adopted blasting to increase their crops.

Subsoiling with explosives may be done at any time of year that the ground is dry. Usually it is best done in July, August or September. Don't attempt to subsoil wet land. To do so is the same as to plow wet ground. The effect of the explosive on wet ground is to cake it and pack it, to form cavities underground —instead of to powder and pulverize and loosen it. The only unfavorable results ever noted from subsoiling were due to the fact that the ones who did the work failed to heed this point.

The first thing to do in preparing the soil is to put down a few test holes over the field. Learn the type and thickness of the underlying ground down six or seven feet. Test different parts of your field. One end of it may be quite different from the other.

Put the charge down two to four feet deep and use half a stick in each hole for all ordinary ground. In very heavy clay or thick hardpan, the charges may be increased to a whole stick or more. These charges should be located *in the hardpan* if there is hardpan. If there is a thin layer of stiff clay put the charge above it. If the charge is placed underneath, it will expend its energies in the soft ground underneath rather than break up the harder ground above.

Put down several experimental shots and observe the effect. *The blast should heave the ground and loosen it to the surface, but not blow out.* When blasts throw much more than dust into the air it shows that energy is wasted, and that the charge should be reduced.

Half stick charges should be placed fifteen to twenty feet apart in fields or six to ten feet apart in gardens. Whole stick charges when five feet deep should be placed twenty feet apart. In rare cases, where there is excessive hardpan, two stick charges six feet or more deep and about twenty-four feet apart, or even heavier charges may be used at greater distances apart. The charges, whatever their size, should always loosen the ground but not blow it out. When subsoiling charges are placed properly, there is little danger above ground, and you may stay within fifty feet when they explode. Tamping the holes solidly with damp clay or sand helps to confine the effects of the explosion under ground. If the hole is not tamped solidly gases will tend to blow out a mere post hole.

The holes may be made with a subsoiling bar when they are only two or three feet deep, but when four or five feet deep they can be made best with a dirt auger. One man can make and load twenty four-foot holes in an hour, after the cartridges are primed. Directions for preparing the charges are given on page 24.

Firing may be done either with ordinary caps and fuse or with the electric blasting machine. Where charges are close together, the blasting machine is much the better because the simultaneous explosion of the charges makes the work more effective.

The proper explosive to use for subsoiling is Atlas Farm Powder. This Powder is compounded especially for this purpose and nothing better is made. Thirty to fifty pounds of Atlas Farm Powder are required to subsoil an average acre. The average price for this quantity is $4.50 to $7.50. The amount of blasting material required is given in detail in the following table. This table is based on half-stick charges. If heavier charges are used, add the cost of additional Powder to the total.

Distance Apart of Charges	Sticks per Hole	Pounds Powder Per Acre	No. Hole Per Acre	No. of Blasting Caps Per Acre	No. of ft. of Fuse Per acre in 3 ft. Holes	Approximate Cost of material PerAcre
15 feet	½	49	194	194	582	$12.20
18 "	½	32	128	128	384	8.00
20 "	½	28	109	109	327	6.93

The effects of subsoiling are more or less permanent. Even if the ground is not cropped as it should be, the effects will last four or five years. When the ground is cropped properly the good effects of thorough subsoiling will be noticeable for fifteen years. Plant annual crops that will fill the soil with a mass of roots for six feet down. As these roots die each year when the plants are harvested, they add enormous quantities of organic matter to the soil.

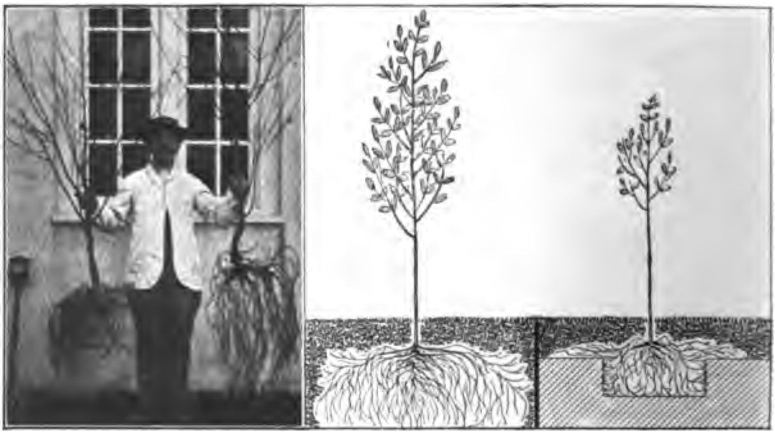
Nursery ground always should be subsoiled with Atlas Farm Powder. On ground so treated, young trees grow very straight, smooth, and large. Photo made at Harrison's Nurseries, Berlin, Md.

In mountain sections, by subsoiling your orchard with Atlas Farm Powder you secure abundant moisture storage. This enables you to use the grass mulch system of culture.

Clean cultivation in orchards is the rule in many sections where dry weather comes often, but no matter how thorough the surface cultivation, subsoil with Atlas Farm Powder.

Berry plants make a vigorous growth all summer on ground subsoiled with Atlas Farm Powder.

Apple tree and its fruit in subsoiled ground. Planted in 1901, it yielded: 1907, 1½ bushels; 1908, 2¾ bushels; 1909, 3 bushels; 1910, 10½ bushels; 1911, 12 bushels; 1912, 14 bushels; 1913, 13⅞ bushels. Photos from H. M. Magee, Waynesboro, Va.



Photograph at left shows two trees, the one on your right dug up from blasted ground, the other from unblasted ground, at the New Jersey Experiment Station. Drawing shows, at left, how roots develop in blasted ground, and at right, how they are limited in spade-dug holes.

BLASTING TO PREVENT WASHING ON HILLSIDES AND SLOPES

One of the great troubles on hilly farms is washing. Many farmers have to leave a stretch of sod across the middle of hill fields, when the rest is cultivated, to prevent half their topsoil from going down to the road at the bottom of the hill when heavy summer rains come.

Blasting subsoil is very effective in preventing this. By working over the entire area with half-stick charges placed three or four feet deep, the absorption of the ground is increased so much that it takes up the rain as fast as it falls. Even a forty-eight hour downpour will not fill the ground to the point where there will be much surface wash.

BLASTING SAVES FERTILIZERS

Commercial fertilizers ordinarily are put in soil in a very fine and readily soluble condition. When heavy rains fall on ground not subsoiled, there is a large amount of surface run-off of excess water. This carries with it a considerable proportion of the fertilizer as well as other plant food.

Ground subsoiled with Atlas Farm Powder is opened up thoroughly to a depth of several feet. When commercial fertilizer is applied to such ground, the rains merely wash it down into the subsoil, where it is retained. The better moisture conditions in the blasted ground also help the roots to absorb the fertilizer more readily.

EVIDENCE

"I have used dynamite in tree planting on some 2,000 trees, and am very well satisfied with the results of the work."

WM. H. PRATT, The National Valley Bank, Staunton, Va.

"We use quite a lot of dynamite for tree planting. We are planting 8 acres of pecans, with fruit trees between, and are using dynamite for all."

W. C. REED, Vincennes Nurseries, Vincennes, Ind.

"All of my apple trees were dynamited. The difference between the trees where dynamite was used and those where dynamite was not used is almost beyond description. The spade-planted trees are practical failures, both as to growth made and the number of trees that lived. It took 22 trees to replant those that died among 11,000 planted with dynamite. It took 131 trees to replant those that died among 400 planted without dynamite. Dynamited trees made an average growth of 4 feet and there are plenty of trees that made a growth of 7 feet. Unblasted trees made a growth of from 6 to 12 inches."

J. N. McBRIDE, Norfolk, Va.

"I shot 3100 pounds of dynamite last year. I blasted all kinds of ground. I drained water holes with dynamite that could not be drained in any other way. Forty acres in Harvey County for Mr. Schragg were drained with 50 pounds of dynamite. The land is in perfect condition yet. In Pawnee County three years ago, I drained a 40-acre pond for Edward Ford with 25 pounds of dynamite. The water was 3 feet deep when we started. In 36 hours the land was dry. I don't believe there's a pond of water in the state of Kansas that I could not drain with dynamite unless it is fed by a spring."

A. G. CRABB, Hutchinson, Kansas.

PREPARING THE BEDS FOR TREES WITH ATLAS FARM POWDER

Blasting the soil for trees makes young trees begin to bear a year or two sooner, and makes all fruit trees bear heavier crops of finer fruit. It provides free drainage, gives water-storage capacity to the soil, and gives the roots an opportunity to develop. In blasted soil the root systems of trees will develop two or four times as large as they will in ordinary holes. How they do this is shown in the drawings and photograph on page 32.

Blasting soil for trees also hastens the chemical and the bacterial action in transforming insoluble plant food elements, and thereby increases the plant food available for the roots. The benefits in this respect are beyond estimating. If you have not read pages 9 to 17, which explain this, turn back now and study them.

Blasting tree holes saves work. Of course, you can dig out enough ground in a few minutes to let the roots be stuck in and covered up in some kind of way, *but if your trees are to be planted right,* it will take time to dig the holes large enough and to fill them in with topsoil and set the trees solidly. When soil is blasted properly, no digging is required. The ground is loose enough and fine enough. You need only lay out two or three shovelfuls of dirt and cover and pack the roots.

Regarding tree planting, the United States Department of Agriculture's Experiment Station at Honolulu expresses the problem so clearly that it should be quoted:

"Without the use of dynamite it is necessary to dig the holes at least three feet in diameter and two feet deep. In heavy soils this will require the labor of one man for about an hour. If the hole thus prepared is filled with new soil and the tree planted in it, the tree may thrive for a year or two but the roots soon meet with the smooth and compacted sides of the hole, through which they have great difficulty in penetrating. The tree is in about the same situation as if it had been planted in a large tub. When dynamite is used, however, the cracks are formed in the soils to greater depths than would be reached by hand digging—to distances of five or sometimes six feet on all sides. This makes the very best conditions for the continued growth of the tree. For tree planting dynamite is recommended confidently as the best method of preparing the soil."

In all loam or heavy soils, the water-storage capacity is increased by blasting. In a very heavy deep clay, blasting only where the trees are to stand may result in water standing in the bottom of the loosened soil where blasted. Surrounding this may be a water-tight wall of hard or unloosened soil. The remedy is to blast the entire subsoil of the orchard. This should be done in every orchard, although it is better to blast only the tree holes rather than not to blast at all.

The charges for blasting tree holes should be about a half-stick of Atlas Farm Powder placed two or four feet underground. Once in a while, in very heavy hardpan, it may be necessary to use a whole stick or even a stick and a half of Powder deeply placed. Half-stick charges usually are enough. Put the holes down with a subsoil bar and sledge, or with a dirt auger. The effect you want is to heave or swell the ground. Don't permit the blast to blow out. Put the charge at a depth that will produce the right effect. Tamping the holes tightly helps to prevent blowing out.

Within a day or two after the charges are exploded, go to the holes and with a stick or bar ram full any cavities under the ground where the explosions took place. One orchardist instructs his men to "dig out the smoke" after each blast. The idea is to see that there are no air spaces under ground. If trees are to be planted immediately, be careful about this. When blasted "holes" are left over winter, the frost and snow and air will mellow the blasted earth, and the rain will fill up all cavities. One rule that must be obeyed when blasting tree holes is to do the work only when the ground is dry. Aside from this you can blast any time of the year, and from one hour to a whole year before you set the trees.

BLASTING IMPROVES TREES AND CROPS

In old orchards the ground usually is packed solidly from the rains and tramping of many years. It stores little water, contains few beneficial bacteria and almost no air. Most of the rainfall runs off the surface because it cannot penetrate the compacted ground. In such soil trees starve because of lack of plant food, and they cannot even send their roots through the ground to secure sufficient anchorage. You can change such ground to rich and fertile soil without damaging the trees by using Atlas Farm Powder.

Even newly planted orchards where the ground is not subsoiled are subject in a measure to the same conditions. The top six inches or more of the ground may have been plowed and worked thoroughly, but underneath this the same old conditions prevail. Plant food is scarce, no water is stored, and the young trees fail to find encouragement in their desire to grow. Such young orchards fail to bear for many years.

The remedy is to blast the soil all over the orchard. This will bring a high degree of tilth immediately, particularly if the blasting is followed by planting of the right kind of soiling crops, as explained previously. The blasting will also provide the water storage, and will put the ground in a condition to absorb and hold moisture enough for the trees in the driest weather. It will cause a great enlargement of the root development of all the trees, and will set in motion processes that will release unlimited amounts of plant food. Trees bear a year or two sooner in subsoiled ground, and yield heavier crops.

Use light charges of one-quarter to one-half a stick of Atlas Farm Powder placed from five to fifteen feet away from the trees. The distance from the trees that it is safe to explode the charges depends upon their age. Young trees can have the charges very close if only a small amount of Powder is used. With old trees the blasts should be placed underneath the outer ends of the limbs. Sometimes it is safe to blast directly under the trunk, 12 to 15 feet deep.

In thick hardpan or clay a good way is to place charges of one to three sticks of Atlas Farm Powder so deeply that they will not blow out, but merely heave the ground. Half-stick charges usually will need to be about 2½ feet deep. A charge of proper strength in comparison to the depth will work sideways almost twice as far as the hole is deep. This rule may govern the distance between the holes.

A few experimental charges will show you how deep to place the charges and how much Farm Powder to use. Charge so the blasts do not blow out, but only heave the ground. In young orchards the best plan is to explode systematically either one or two charges on a direct line between each two trees. Atlas Farm Powder is the one best explosive for this because it cracks and opens the soil without shattering and tearing roots. Do the blasting after the growth is over in the late summer or fall, or in late spring before the leaves have reached their full size. *Blast only when the soil is dry.* Wet soil will pack and cake instead of powdering and cracking.

Shade trees which are not making a proper growth may be benefited immediately by blasting the subsoil with Atlas Farm Powder.

EVIDENCE

"I have used great quantities of dynamite for blasting tree holes. The land here in Dade County, Florida, is extremely rocky. My method is to place a heavy charge at the bottom of a hole about 2 feet deep. I leave the broken rock in the hole. Dynamiting is a great advantage in our rocky soils. The larger part of the citrus groves set by me have had dynamite used where the trees were set."

E. V. BLACKMAN, Miami, Florida.

"I dynamited rocks on an acre and a quarter of land that was too rough to drive over. It was a tough field. Before dynamiting it was worth only $5 an acre. Now it is worth at least $200 an acre. From this piece of land I have just harvested a crop of winter wheat that went 40 bushels to the acre and averaged more than 5 feet high."

GEORGE V. SMITH, New Haven, Conn.

"We have proved conclusively that dynamiting in tree holes insures a rapid growth of strong fruit wood, and personally I believe that the trees planted in dynamited holes bear fruit one year earlier than the old style planting. Our 1913 planting in dynamited holes averaged more than 96% of live trees at the end of the growing season. A 15-acre orchard with 780 trees shows on inspection after the growing season only two dead trees, and these were defective when they left the nursery."

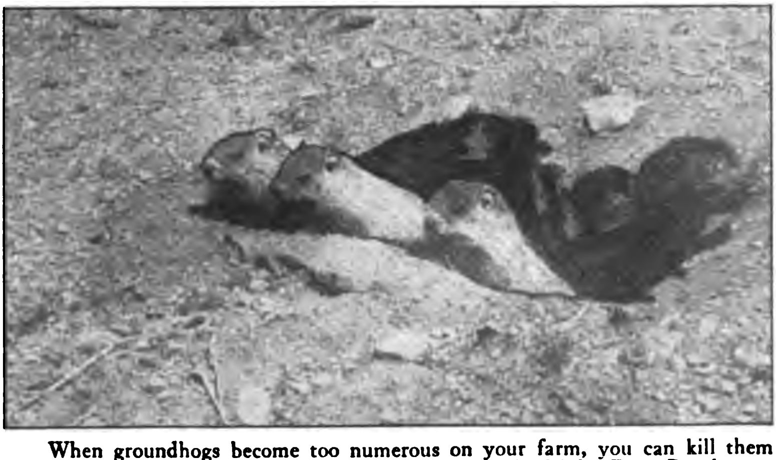
H. M. MAGEE, Waynesboro, Va.

"About 15 years ago I wanted to drain a muck pond. It contained about 3 acres, and the ditch had to be cut through a ridge about 6 feet high on the side and 300 feet wide. The ditch to be made had to be 7 feet deep, 18 inches wide at the bottom, and 5 feet at the top. The explosive used threw out the hardpan for 100 to 150 feet at each side of this ditch. This hardpan would not grow anything at all before it was exposed to the air, but immediately it was exposed, the insoluble plant food elements were mellowed and broken down, and I found that several grasses that would grow only in fertile soil had started in to grow luxuriantly in this disintegrated hardpan. The sickly palmettos on the ridge along the ditch began to boom, and the sapling pines made an exceptional growth."

FRANCIS K. ADAMS, Punta Gorda, Fla.

In market and home gardens nothing will take the place of explosives in preparing the ground and in keeping it in best condition.

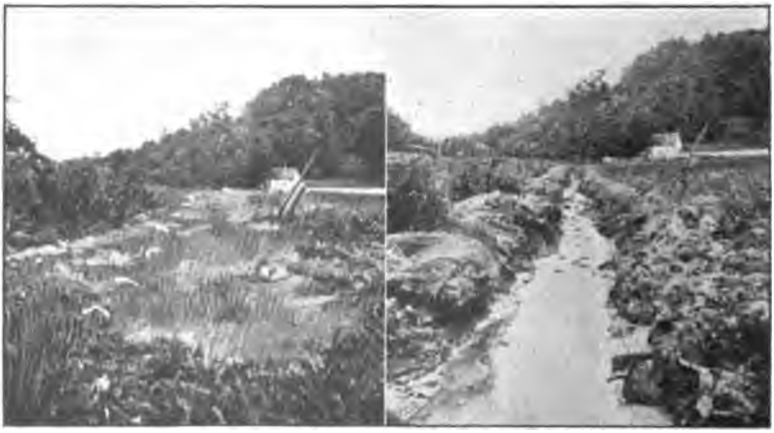
Shade trees and hedges as well as fruit trees and farm crops are greatly benefited by shaking up their beds with Atlas Farm Powder.



When groundhogs become too numerous on your farm, you can kill them quickly by exploding far back in their burrows one stick of Atlas Farm Powder.

Ditch blown through sandy loam at Wilmington, N. C., with Atlas Farm Powder.

Ditch blown through damp sand at Wilmington, N. C., with Atlas Farm Powder.



Wet land before blasting ditch with Atlas Farm Powder and the same ground after the ditch was blown.

HOW TO MAKE DITCHES OF ALL KINDS CHEAPLY WITH ATLAS POWDER

Ditches of all sizes from the smallest to the largest should be dug with Atlas Powder. Blasting ditches is much easier, quicker and cheaper than any other method. Any intelligent man can learn to do it in half an hour. Where ditches are dug by hand the cost usually runs around 25 cents a cubic yard of material removed. If teams can be used, the cost comes to 12 cents a cubic yard.

Both of these methods consume much time. To dig a ditch of any considerable length will keep two or three men busy several weeks. With Atlas Powder the same ditch can be made in a day or two by one or two men, and the cost of doing it would average only 4 to 8 cents per cubic yard of material moved. A ditch three to four feet deep and three to five feet wide can be blasted at a cost of about 4 to 6 cents a running foot. Smaller ditches cost less and larger ditches cost more.

With the shovel or team method of making ditches, the work usually has to be done during the summer when the ground is dry, just at the busiest time of the year. Explosives for ditch digging work most efficiently when the ground is wet, and ditches may be made with Atlas Powder in the spring or during the wet periods in summer and fall when other farm work can not be done.

You can make a ditch through any kind of ground with Atlas Powder without preliminary work. No matter how thick the brush or how swampy the ground may be, all you need to do is to climb through, place the charge, and the explosive will do all the clearing necessary. If you dig ditches through such land by hand or with a team, you have to spend a lot of time removing brush or stumps.

Another great advantage of a blasted ditch is that the explosive may be made to scatter the dirt for many feet on either side of the ditch. If you prefer to have the dirt on one side, do the work on a windy day when the wind is coming from the desired direction. A properly blasted ditch will need little or no shoveling. The banks will be reasonably even as soon as the blasting is done, and they always square up nicely after the water comes in. See engravings on page 38.

The only tools required for preparing the holes for blasting ditches are a sledge and bar or a dirt auger. The latter is preferable nearly every time except in very wet ground. Ditches up to five feet wide at the top can be made with one row of holes or charges; if between six and twelve feet wide, two rows would be required, and from twelve to twenty feet three rows of holes. The distance between the rows of holes should be 2½ to four feet. When more than one row of holes is used, the charges should be "staggered" or alternated.

The amount of each charge, the distance apart of the charges in the row, and the depth of the holes depend on the character of the soil and its condition. Heavy clay, such as clay and muck, always is thrown out better than light soil. That is, Atlas Powder will throw out a bigger ditch in heavy soil than in light soil. If the ground is wet the charge will throw out the ground better than if it is dry. Wet soil takes less explosives, and the ditch made in it will be larger than in dry soil, and more even.

The accompanying table shows the amount of Powder required, the proper charges for each hole, the depth of the holes, and the approximate cost of the Powder per 100 feet of ditch for various sizes of ditch.

AVERAGE COST OF BLASTING DITCH

Size of Ditch		Average cost	Sticks to	Depth of
Depth	Width	of powder	charge	holes
2 feet	3 feet	$5.00	¾	15–18 inches
3 feet	5 feet	7.00	1	30 inches
4 feet	6 feet	7.50	1½	30 inches
5 feet	7 feet	8.50	2	42 inches
5 feet	12 feet	13.50	1½	42 inches (two rows holes)

These figures apply to very damp heavy ground of the average farm. In some sections of the country, the same size ditch can be made much cheaper while in a few other sections the cost may run higher, particularly if the ground contains many stumps, roots or flat stones.

You cannot expect to do satisfactory ditching in frozen ground. Put it off until the ground thaws. If hardpan or rocks are close to the surface, put the charges down *on top* of this, but not *in* it. Experiment before you charge many holes. Try the different soils along the line of the ditch. Try different amounts of Powder placed at different depths and at different distances apart. Only in this way can you learn how to make the best ditch at the least cost. Proper methods make perfect ditches for very little money.

A great many ditches on the average farm are what might be called minimum ditches or smallest ditches. The idea is to get a deeper and more permanent ditch than a plow will make but not a large one. For a ditch of this kind one row of three-quarter stick charges placed fifteen to eighteen inches deep usually is the amount of explosive to use. Where sticks are cut in two, the exposed end of the Powder should be covered with tallow, clay or soap, to prevent water from soaking into the cartridge.

Put the holes down to a depth within six inches to eighteen inches of the desired depth of the ditch. It is best to make the holes with a 1½ inch bar or auger. Don't get the charges too deep in the ground, because the explosive works more efficiently when placed rather shallow.

The charges should be tamped fairly well unless water almost fills up the holes. Fire charges within half an hour if the water covers them. Explosives will work better in all ditching if the temperature of the soil or the water is higher than 35 degrees. See paragraph on chilling of Powder, page 59. If the soil is only damp, or is dry, the charges may be left in them for several hours without losing strength.

Firing the charges may be done with fuse and caps, or with electric fuzes and blasting machine. When conditions are right only the centre charge of the row needs to be exploded directly. In ground that is wet or reasonably damp, particularly if it is clay or heavy muck, if you prime and fire the middle charge of one row of holes, the whole row of charges will be exploded, when the charges are close enough together. It is the shock wave from each explosion traveling to the next one that does the work. Under proper conditions this shock wave travels through the ground from the charge to charge faster than you can detect it when the explosion takes place. The explosions occur almost simultaneously.

In order to insure the success of this method of firing, charges of one stick to a hole must be placed within fifteen to thirty inches of each other. If 1½ or 2 sticks are used in each hole, the charges may be as far as 30 inches apart. Where three-quarter stick charges are used, the distance should be not more than 16 to 20 inches and the ground must be wet.

This method of firing the charges is, of course, much easier, quicker, and less expensive than where each separate hole has to be primed, and it should be taken advantage of whenever possible. Where there are two or three rows of holes with thirty inches or more between the rows, it is necessary to fire the centre charge of each row with a blasting machine, or put one extra charge between the rows at the center charges. Firing one of the center charges then will explode all the rows. Load two or three charges in each row at the center with half again as much Powder as you use for the other holes. It is best to use two sticks at least, and if the charges are placed thirty inches apart, use three sticks to start. These center charges may be fired with ordinary fuse and caps or with a blasting machine and electric fuzes.

Whenever the ground is only damp, or is dry, and when the soil is sandy or very light, the shock from the center explosion will not travel through the ground with sufficient strength to explode the adjoining charges. Also if there are many stumps or roots in the ground or flat stones on their edges, sufficient shock to explode the next charges will not be transmitted. Hardpan, to a certain extent, and frozen ground, also prevent the shock from traveling through the earth. To blast ditches satisfactorily, under these conditions, it is necessary to prime each charge, and fire with an electric blasting machine. This enables you to put off all the charges at once, and their combined forces, acting simultaneously, accomplish more work then they would if exploded one at a time, or if there were a second or more of time between the explosions. Ordinary fuse and caps may be used for short ditches if a blasting machine cannot be had.

The method of priming the cartridge and connecting up the wires is explained fully on pages 24 to 28. Load and prime with electric fuzes as many holes in the ditch as the temperature of the ground, the amount of water present and the capacity of your blasting machine will permit, and then fire them all together. If the water does not cover the charges in the holes, a loose tamping of dirt is required for best results. See that the electric fuze wires connecting the charges are properly twisted together and before you fire the charges see that everybody is out of the road.

Where a blasting machine is used the charges may be placed as far apart as you want to put them. Four feet often is not too much. Heavy charges must be used in each hole. The distance apart may be greater when the holes are shallow.

If trees or stumps stand in the line of the ditch or near it, move them at the same time the ditch is blasted. See page 47 for the proper amount of Powder to use under them.

The proper explosive to use for making small ditches in dry ground, where each charge is primed and the firing done with an electric blasting machine, is Atlas Farm Powder. For all other ditches use Atlas Powder 50 per cent. or 60 per cent. This is the better explosive to use when you fire the charges by the transmitted shock method. Where the work is wet be sure to get waterproof fuse or electric fuzes as the case may be. When the charges go under water, be sure that the joints where the caps and fuse come together and where the caps and fuse or electric fuzes enter the cartridge are made watertight with tallow.

DRAINING SWAMPS WITH ATLAS POWDER

In many swamps and ponds the water is held only by underlying layers of clay or hardpan. Underneath these watertight strata is an open layer of earth which will carry away the water.

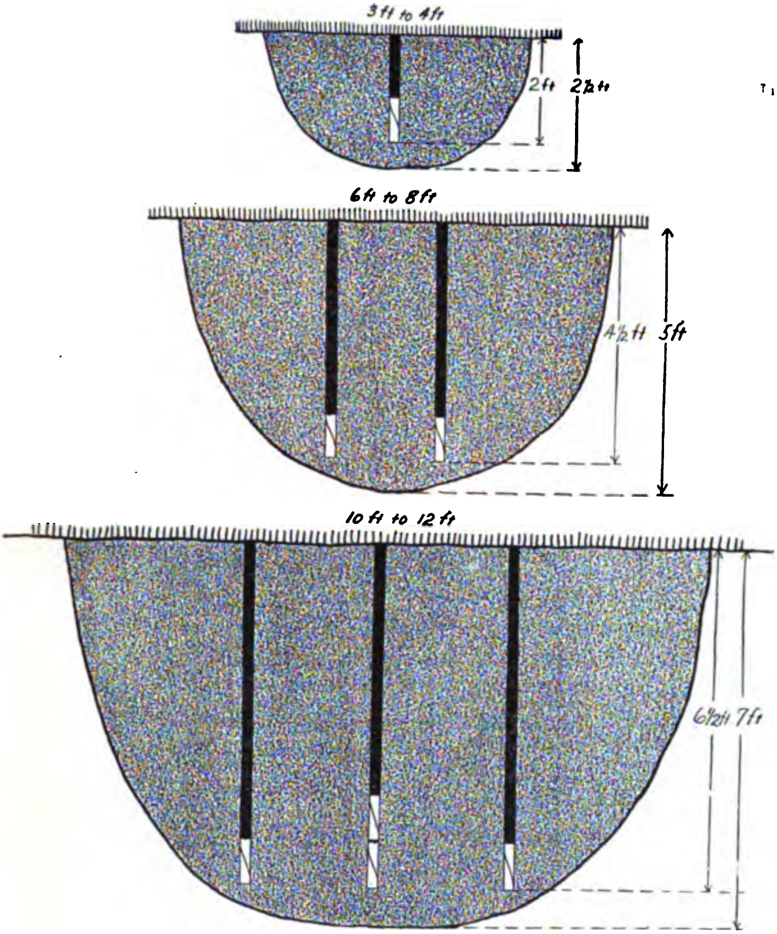
Such places may be drained by blasting openings through the hardpan or clay down to the open ground underneath. Put down one or more test holes through the bottom of the pond until you strike loose ground underneath the hardpan or clay. You may have to go down as much as thirty feet to do this, or you may strike it within six feet. A pond or swamp of half an acre usually may be drained with one blast.

An extension dirt auger is best for making the holes. Put the hole down to the depth previously determined upon by the test holes, then "spring" it at the bottom with one stick of Powder. This will close the hole up slightly, but it can be opened easily. Fire this charge the same as you do the main charge.

After giving the hole a few minutes to cool, lower the sticks of the main charge and press each one to the bottom of the hole. The primer should be a whole stick of Powder fitted with waterproof electric fuze. If water fills the hole you need no tamping. If it does not, tamp the hole solidly.

The amount of explosive to use depends upon the depth of the hole and the thickness of the hardpan. If the hole is 6 feet deep, a charge of 4 sticks of Atlas Powder 60 per cent. is enough; an 8-foot hole should have 6 sticks; 10-foot holes, 8 sticks; 15-foot holes, 10 sticks; 20-foot holes, 15 sticks; and 30-foot holes, 20 sticks.

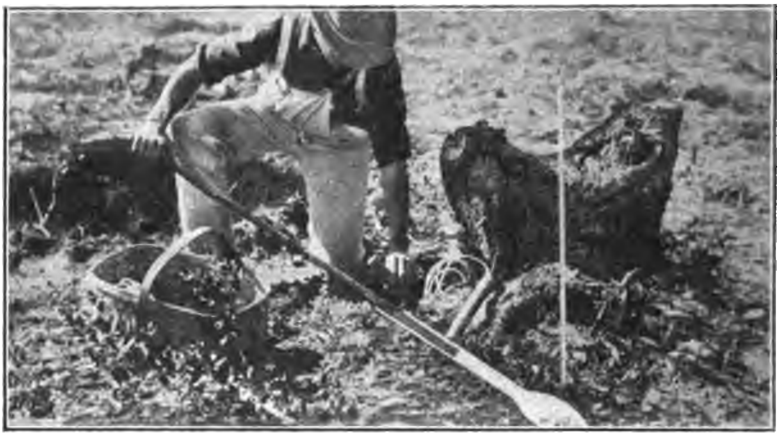
If your pond or swamp fills with water only during the wet season, do the blasting in the dry season. If water stands too deep to permit you to wade, do the work from a raft. Make the raft with a hole through the center and run a three or four-inch pipe down through this to the bottom. Do your drilling through this pipe. When the hole is loaded remove the pipe and raft.



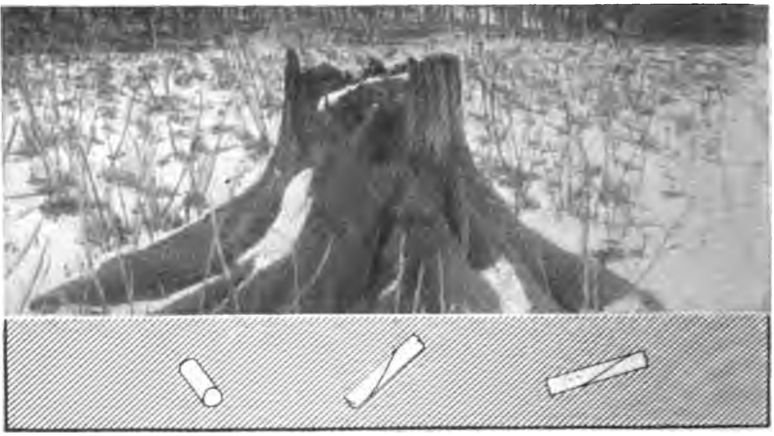
How the charges should be placed for digging ditches of different widths and depths. See complete directions on page 39.

Canal through a levee along a river, made entirely with Atlas Powder. This photograph shows what ditches it is possible to make.

Two ditches made with Atlas Powder without any shovelling, hand or horse handling of earth whatever.



How to place Atlas Farm Powder under a hardwood stump. Charge is directly beneath the centre of the stump, pretty deep, and is not left in sticks.



Big pine or other long rooted stumps, are removed best by placing two or three charges as shown, and exploding all at once with an electric blasting machine.

HOW TO REMOVE ALL STUMPS QUICKLY WITH ATLAS FARM POWDER

Every stump in your fields causes you much loss. Breakage of tools such as plow-shares, singletrees, harness, part of mowing machines and binders is one of the smallest items. It takes far more time to turn out for the stumps than it does to drive directly over the place where they stood.

The average stump takes up or prevents crops from occupying almost a square rod of ground. If there are thirty stumps to the acre, they occupy nearly one-fifth of the total area of the field, and if the crop from the remaining four-fifths is worth $40 an acre, the crop from the whole field when the stumps are removed will be worth $50 an acre. The increase is all profit, because there is no additional expense connected with planting or cultivating the ground occupied by the stumps. If your net profit is $10 an acre, this means an increased profit of 100 per cent.

On some of the best land stumps are so thick that wide harrows, double cultivators, binders, etc., cannot be used at all, and hand cultivation is the only means of growing crops. Only indifference on the part of many farmers explains why lots of stumps are allowed to remain when they should have been removed many years before.

With explosives one man can remove fifty average stumps a day at a cost of only 12 to 20 cents each, including wages and Powder. If three men work together, two of them making the holes and the third preparing the charges and bossing the job, they can do four times as much as one man.

Blasted stumps make excellent kindling, particularly if they are pine or hemlock. The blasting breaks up the subsoil for yards around the stumps. The holes made by the blasts will be filled up almost entirely when you plow and harrow over them. If any depressions remain, they are easily filled up by scraping dirt into them with a plow or by a little shoveling.

The method of preparing the charges and firing them is described in detail on pages 24 to 28. The methods of blowing the stumps are pretty well understood everywhere, but some people still fail to use the best methods. By studying the following suggestions you can remove your stumps most effectively and do it at little cost.

The tools you need are a bar and sledge or a dirt auger. With a few stumps you will also need a long-shank wood auger. If the stumps are a year or more old, the bark and the fine roots have begun to rot and the hold of the stumps on the earth has been loosened to a certain extent. When green stumps must be blasted immediately, they require about half again as much explosive as dead stumps.

The charge should be placed under the centre of resistance of the stump. The actual centre of the stump often is not the place. Examine the main roots and see if one side of the stump has more of them than the other. If the stump is on a hillside, the charge should be slightly up hill from the centre of the stump. Hardwood stumps up to twenty-four inches in diameter seldom require more than one charge. Pine stumps, or any other stumps with long roots similar to pine, when very large, often can be best removed by several charges. Place one under the centre of the stump and one under each of the larger roots.

It is best to have from six to twelve inches of earth between the charge and the wood. The depth to put the charges depends entirely on the stumps. One rule is to put them as many inches under the normal surface of the ground as the stump is inches in diameter at the surface of the ground. That is, if the stump is one foot in diameter, put the charge one foot below the surface of the ground. If the stump is thirty inches in diameter, put the charge thirty inches under ground. This rule must be modified for different soils. Light sandy soil requires deeper placing of charges than heavy clay soil. Stumps blow out with less explosive in clay than in sand. In very light soil it pays to blast pine stumps with more than one charge, of course firing them all at once with a blasting machine.

Long rooted stumps require that charges be placed deeper than short rooted ones. In blasting stumps with very large tap roots that go straight down into the ground, it is sometimes of advantage to bore into these tap roots with a wood auger and place the charge right in the wood. You usually can throw out such a stump as this by placing the charge against the side of the tap root. Don't start your hole too far away from the stump. Nearly all stumps have hollows between the roots where you can start the bar or auger and save a couple of feet of boring and of fuse.

When the charges are placed too near the surface, they merely blow off the top of the stump and leave the roots tight in the ground. When charges are too deep they exhaust their energies without throwing out the stumps. But it is better to have the charge too deep than too shallow, because you can get the loosened stump out more easily than you can get out one with the roots left tight.

When blasting a very large stump where one charge of several sticks of explosive is needed, you will have difficulty in getting enough of a hole under the stump to contain the explosive at the right place. Often in putting down holes under any stump, you encounter roots or stones that interfere with the auger or bar. In both these cases a "springing" charge of about a quarter of a stick of Atlas Farm Powder should be exploded at the bottom of the hole as far as you have made it, or entirely down where you want the main charge to be. This will loosen up the soil and make enough of a cavity at the right place to contain the proper amount of Atlas Powder in one charge. The use of this little priming charge will often save an hour's time. A man's time for an hour is worth 20 cents or more. The Powder and fuse cost about 4 cents. Be careful to give the hole fifteen or twenty minutes to cool before you put in the main charge. If you do not, the heat of the previous explosion may explode the Powder.

Three or four sticks, end to end, make too long a charge. It often will simply split the stump in two instead of breaking it up into several pieces and blowing it out. After you spring a hole with the small charge, slit each stick lengthwise in three or four places, and when you press it home with your tamper, it will swell out. In this way a charge of three or four sticks will make a round bulk just at the right place. Such a charge radiates its energy much better for the purpose than the long charge.

The quantity of Powder required for different sizes and kinds of stumps varies with the time since the stumps were cut and with the kind of soil. The harder and heavier the soil is, the less powder is required, and the looser and lighter it is, the more is required. When the ground is frozen in the winter is a very good time to blast stumps out. The minimum of Powder will do the work then. For this purpose Atlas Farm Powder is exceptionally valuable because it does not freeze at any ordinary temperature.

The following results of stump blasting done by the Kentucky Experiment Station and by one of our own men will show you what charges were required:

Stump No.	Kind of Stump	Diameter Inches	Sticks Used
1	Dead Oak	12	2
2	“	16	1½
3	“	15	1½
4	Dead Pine	16	1½
8	Dead Oak	8	1½
11	“	30	4½
13	“	18	3
14	“	12	1½
15	“	20	3½
16	“	34	4½
18	Dead Pine	14	2
19	Green Oak	16	3
23	Dead Oak	24	3
25	“	38	5½
32	“	27	4½
39	“	30	6
41	Dead Snag	20	4½
45	Dead Oak	27	5
56	Green Black Gum	16	5½
61	Dead Gum	24	4
71	Green Sugar Maple	16	5½
76	Dead Oak	26	2
96	Green Gum	15	3½

To these figures we can add experience of our own as follows:

Kind of Stump	Diameter Inches	Sticks Used
Dead Walnut	10	1
Dead Hemlock	15	2
Dead Pine	40	7
“	24	5
“	20	4
“	60	12

Some authorities say that you should use about one pound of explosive for each foot of diameter of the stump. This is all right for stumps up to thirty or forty inches in diameter. Larger stumps require 1½ to 2 pounds for each foot of diameter. A rule for the enormous stumps of the Pacific Coast is to square the diameter of the stump in feet and use this figure for the number of pounds of explosive.

After you have blasted a few stumps you will be able to judge almost exactly the number of sticks of Powder required to move any stump. Use enough to produce a dead, muffled report and to lift the stump out of its seat. Extremely loud reports and the throwing of much dirt, etc., into the air show a waste of energy—too much explosive. It is a good plan to carry a note book and a yard stick with you and keep records of the kind and sizes of stumps blown out by the different quantities of Powder.

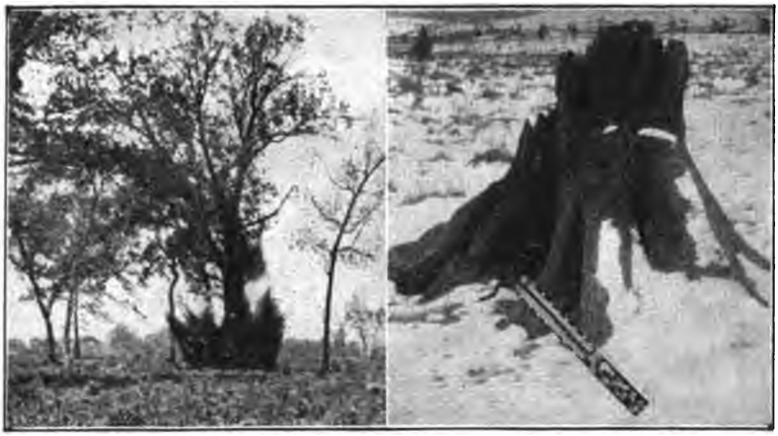
Very large green stumps sometimes are best blasted by splitting them first with a small charge placed fairly shallow, and then blasting each root again as if it were a separate stump. Large willow and cypress stumps can be moved best by boring three to six holes in the ground around them about 18 inches from the stump, and pointing the holes steeply toward the centre underneath the stump. Put one stick of explosive in each of these holes. If the ground is wet and heavy, you need to prime only one charge; the rest will be exploded by transmitted shock as in ditching. If the ground is dry, you must prime each separate charge and explode them all at once with an electric blasting machine.

When blasting hollow stumps, it is well to fill them with dirt, packing it in tightly.

Stump charges can be fired with ordinary fuse and caps, but the safest way and the best way is to use an electric blasting machine. Where the stumps are less than fifty feet apart connect several of them and blow them all out at once. If two or more stumps are close together, exploding the charges under them simultaneously will be more effective than blasting each one separately. A blasting machine also is safer for stump work because there is less risk of misfires, no risk of hang fires, and no danger, unless a damp fuze has ignited it in going back immediately to a charge that has failed to explode.

The proper explosive to use in blowing stumps is Atlas Farm Powder. This explosive has a more lifting and heaving effect than many dynamites used for the purpose. Such explosives tend to shatter the stumps without loosening or throwing out the roots. The only exception to the use of Atlas Farm Powder is in very light sandy soil where long rooted stumps are to be blasted. Here it sometimes is of advantage to use Atlas Powder 40 per cent. or 60 per cent., owing to the fact that the soil is too light to hold the force of the explosion long enough for the roots to give way.

"The advantage of using explosives in clearing new land is that a big investment is not necessary as in case of stump machinery," says the Wisconsin Agricultural Experiment Station. "Explosives can be used in some way by almost every settler. The stumps and boulders are left in such form as to be handled and disposed of easily. The roots are freed from soil and the large parts broken up so they can be used for fuel, as is the practice in many sections at present."

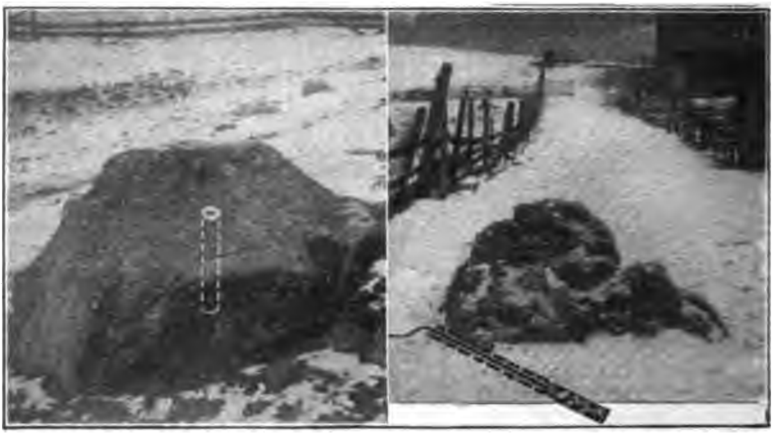


Blasting out a standing tree and how to place one charge properly under a pine stump. Atlas Farm Powder is packed to fill the hole.

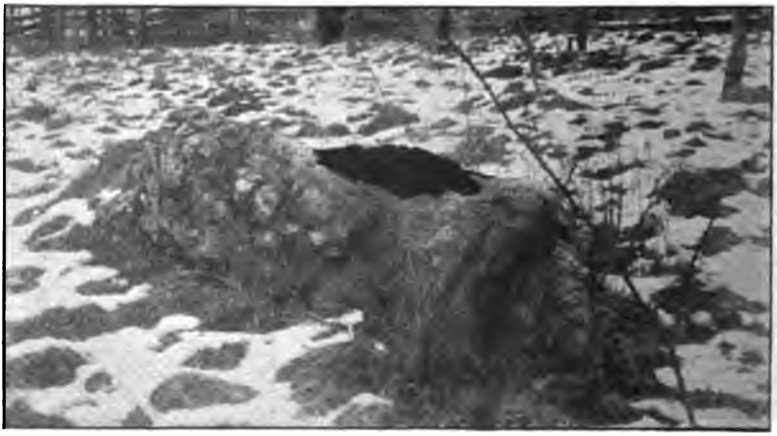
A typical piece of land which would be extremely valuable if cleaned up with Atlas Farm Powder, but which is worthless on account of stumps and briers.

Typical stump land that can be cleaned up effectually with Atlas Farm

Typical tight stones. These may be removed with Atlas Farm Powder.



How to drill a hole in a large stone to break it up with Atlas Powder. How to place charge under tight stones to blow them out and break them up. Don't permit a road to be blocked up with a big stone.



How to mudcap large stones to break them up. Put the Atlas Powder in a depression on a flat side of the rock and cover it with six inches of wet clay.

Better Farming with Atlas Farm Powder

"Where stumps from twelve to thirty inches across have been cut for some time, and the soil is not very sandy or loose, the use of dynamite alone has been found, in practice, to be the most satisfactory method," says the Minnesota Agricultural Experiment Station. "The advantage of dynamite is that it will not only blow stumps entirely out of the ground, but it will remove the dirt from the roots at the same time, and break up the stumps so that they can be easily handled and burned."

"One point seems clear, and that is, that when stumps are to be removed, the cheapest method is by the use of dynamite," says the Kentucky Agricultural Experiment Station.

The United States Department of Agriculture, in Farmers' Bulletin 150, says:

"In the removal of large stumps dynamite is serviceable and economical."

Commenting upon the use of machinery to clear land, the same bulletin says:

"There are many different makes of stump-pulling machinery upon the market. The promoters of these various grubbing devices claim great merit for their respective machines, but catalogue claims should be accepted with great caution.

"In the neighborhood of the writer, and doubtless in many other neighborhoods, can be found such machinery in idleness because it was tested and found wanting. The difficulty with most stump-pulling machines is that if they are strong enough for the work desired of them they are too expensive, cumbersome and unwieldy.

"When these machines are once properly adjusted, their work, provided nothing breaks, will be satisfactory. But the labor of moving and the care of adjusting, together with the liability to breakage, more than outweighs the virtues of any stump-pulling machine known to the writer."

EVIDENCE

"I cleared off 9 acres of stump land. Average size of stumps 3½ feet in diameter, chestnut and oak. They all were blown with battery and Atlas Powder 40%. The cost per stump averaged only 65 cents."

CHARLES V. WEAVER, Easton, Pa.

"I have done a good deal of blasting work with lots of good results. My pecan trees show a great difference in size between the trees that were planted in dynamited holes and those that were planted in spade-dug holes."

F. W. McMURRIAN, Columbus, Ga.

"I often have found myself standing thoughtlessly within two feet of a hole when the blast went off (preparing ground for trees). There is no danger or spectacular show unless the blast is in rock or hardpan. The flying of rock and dirt only demonstrates the inefficiency of the man doing the work. Effective work breaks, cracks, and pulverizes the ground in all directions from the bottom of the hole, and the more noiseless and sightless it is, the better execution is done. What the shock does can be left only to the shovel in the hands of the operator. The merits of the work should be judged by the effects produced in the growth of trees. Every step taken from the blasting of the hole to the superior growth of the trees is so reasonable, so certain and feasible that there is no chance left for doubt."

J. A. TEAGARDEN, Auburn, Cal.

METHODS OF BREAKING BOULDERS WITH ATLAS POWDER

All big stones that stick above the surface of farm land are tool breakers and time wasters. Ledges of rock within reach of plows are almost as bad. They should be broken up with Atlas Powder.

Three methods are used for breaking stones. The first is the "mudcap" process. This is the quickest way. You can gather up your explosive and have your mudcap in place on the stone within five minutes. It takes more of the explosive to accomplish the desired work than if the stone were drilled.

If you can find a crack or hole in the stone, remove the Powder from the paper and pile it in a low cone at this place. Then cover it with six inches of damp clay or sand, first inserting your cap with fuse attached, in the center of the pile. If you can't find a depression, pile the Powder on any flat surface.

No matter how big the stone, look at it as you would if you intended to break it in two with a sledge, and put the explosive right at the place where you would hit it. Don't spread the Powder out over any more surface than you can help. If the stone is buried in the ground, dig a ditch around it almost as deep as the stone to give it a chance to fly apart.

Atlas Farm Powder will break stones well by the mudcap method. Use it if you have a few of them to break. If you have many, particularly if the stones are very large and very hard, it will pay you to use Atlas Powder 40 per cent. or 60 per cent., which has a more shattering effect than the regular Farm Powder. The following table shows the quantities of Atlas Powder required to shatter stones of various sizes by the mudcapping method.

Diameter of Stone	Sticks of Powder Required
18 inches	2
2 feet	3
2½ feet	4
3 feet	5
4 feet	7
5 feet	10

The second method of getting rid of the stones is to put Farm Powder directly underneath them. If they have a flat side next the ground you can break them up in this way almost as much as with a proper mudcap. If they are round on the underside, the best way is to put a light charge underneath them and throw them out, then break them with a mudcap.

Drill or punch a hole underneath the stone with an auger or crowbar. Be sure that the charge is directly under the centre of the weight of the stone. Tamp it very firmly. Inspect the ground carefully all around the stone to see that there are no openings where the explosive can blow out. The idea is to confine the explosion entirely under the stone.

A very light charge will throw stones out. One-fourth to one-half of the quantity given in the table for mudcapping is the right amount to use. If the stone is to be only thrown out, no explosive is so good as Atlas Farm Powder. If it is to be shattered as well as thrown out, then Atlas Powder 40 per cent. or 60 per cent. has slight superiority, but not enough to justify you in purchasing Atlas Powder 40 per cent. or 60 per cent. especially for the purpose unless you have a large number of boulders to break.

The third method of breaking up stones is to drill them and put the charge somewhere in toward the centre of the stone. A hole an inch in diameter or less is big enough. Comparatively small charges of Powder are required. In a boulder five or six feet in diameter drill a hole thirty inches deep, and put in two or three sticks of Atlas Farm Powder, or one and one-half to two sticks of Atlas Powder 40 per cent. or 60 per cent. Be sure that the charge is tamped solidly. Empty the Powder out of its paper shell and pack it directly into the hole. A stone two feet in diameter may be broken nicely with about one-half to two-thirds of a stick of Atlas Farm Powder in a hole eight inches deep. Smaller stones may be broken with shallower holes.

Ledges of rock which outcrop or which come within reach of a plow, or even within reach of roots, are detrimental to many fields. To break up these rocks, we recommend Atlas Farm Powder, unless the charge is used in mudcapping on top of solid rock, when 40 per cent. or 60 per cent. is better.

Outcropping rocks such as these nearly always lie in veins or shingles. If you can get the explosive located well down underneath a shingle ridge, the obstruction will be shattered to quite a depth. Use a rock drill and put the holes down as far as you want the rock cleared away. In slate every 8 or 10 feet is close enough for the blast. In granite or limestone they will have to be nearer.

Charges of one or two sticks are heavy enough, the former when the charges are to be within eighteen inches of the surface, and the latter when they are two or three feet deep. A ledge often can be removed at an expense of $6 or $8, when the loss it causes almost equals that amount every year.

In all kinds of stone blasting, you must be certain that your fuse is long enough to let you get away 100 to 150 yards, or even further, before the explosion takes place. Stone blasting is dangerous work. Heavy blasts will throw rather large pieces of stone to considerable distances. The best way of firing the charges in blasting stone is to use an electric blasting machine, located 150 yards away. Then you have to be 150 yards away to fire your charge. Ordinary fuse and caps can be used.

QUARRYING WITH ATLAS POWDER

It is better to expose the rock you want by stripping the dirt off it. You can blast this off cheaply with explosives.

After the rock is exposed, it may be broken up with Atlas Powder in a mudcap charge, as described in boulder blasting, provided there is a projecting ledge. A better way is to drill a hole into the rock. Deep holes and heavy charges will bring down more rock in proportion than shallow holes and light charges.

If you are buying explosives especially for quarrying, get Atlas Powder 30 per cent. or 40 per cent. Regular Atlas Farm Powder will do the work very well if you have it on hand.

THE WAY TO DIG POST HOLES EASILY WITH ATLAS FARM POWDER

Unless the ground is very loose, post holes can be dug much faster and much cheaper with the help of a little Atlas Farm Powder than with bar and shovel or a post hole digger.

Put down 1½ inch holes with a bar or dirt auger about the depth you want the hole to be. Then explode no more than a half-stick of Atlas Farm Powder at the bottom of this hole. Use no tamping whatever.

The Powder will blow out the hole to a certain extent, and the action will be to loosen the ground for only six inches or so around the hole. After this charge is fired, the ground, slate, etc., may be shoveled out easily.

Explode the charge either with a blasting machine or with ordinary caps and fuse. Try a few holes to learn the best depth and charge.

EXCAVATING FOR FOUNDATIONS

In excavating, proper blasting with Atlas Farm Powder or Atlas Powder will save much work. You can take out a layer of dirt four feet deep with Atlas Powder 40 per cent. by putting charges of two sticks about three and one-half feet deep and about every five feet over the cellar area.

Keep the charges two or three feet from the sides. If the excavation is to be made deeper than four feet, go over the same ground with a second series of blasts put down three or four feet or less from the new bottom.

If nearby buildings prevent you from using heavy charges, use light charges to loosen the ground. If you find rocks near the edges, blast the center of the cellar out first. Then drill holes where you want the edges of the excavation to be, and these blasts will throw the dirt and stones to the center while keeping the side walls straight.

ROAD MAKING WITH EXPLOSIVES

Where dirt has to be moved, rocks broken up, or cuts made in road building, explosives will hasten the work very much. If stones are to be blasted, proceed just as you would for quarrying or for breaking up boulders.

If you want only dirt or slate loosened, use charges of one-half to one stick of Atlas Farm Powder placed three feet apart. Where cuts have to be made, use charges heavy enough to throw the dirt entirely out of the road. Place them down almost to the grade of the road. In this way you will have little material to handle with shovels or scrapers.

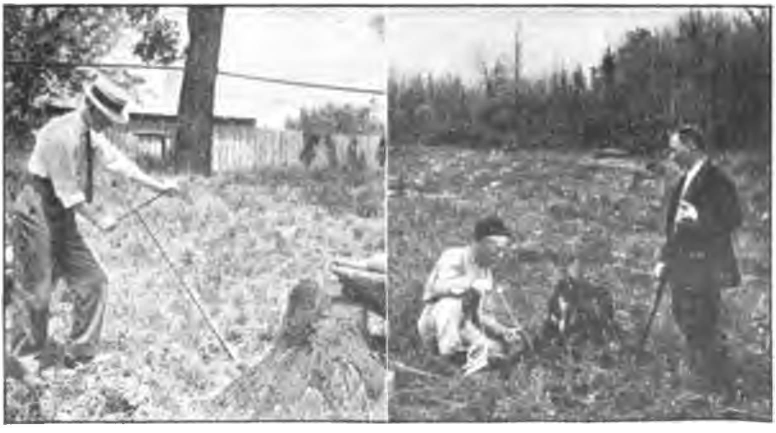
EVIDENCE

"We have used dynamite for various purposes, including blasting stumps, ditches, tree planting, etc., and have secured very satisfactory results."

STARK BROS. NURSERIES & ORCHARDS CO., Louisiana, Mo.

How large boulders are broken up by properly placed charges of Atlas Powder. See page 52.

Ice gorges frequently cause serious flooding by damming back streams. They may be removed in five minutes with a few pounds of Atlas Farm Powder.

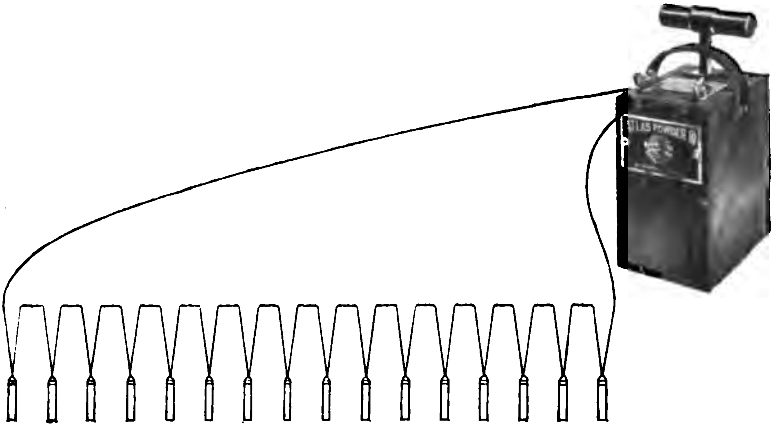


Stages of the work of blasting small stumps. Boring the hole and lowering the charge by the fuse.

In subsoiling, holes often can be put down quickly with bar and sledge.

This blast is good for stump blowing but bad for subsoiling.

In blasting large stumps when the ground is dry, a great dust often is raised. It is an easy quick way to clear new land.



Connecting the wiring with electric blasting machine. The electric fuze wires are connected together in series (see page 28) and the outside wires of the end fuzes are connected to the leading wires and these to the blasting machine.

BREAKING UP ICE GORGES WITH ATLAS FARM POWDER

Some of the most fertile farms are located in creek bottoms where ice often dams back the water so that it covers fields, destroys fences, and often floods buildings. A few pounds of explosive will remove any ordinary gorge and save trouble and loss.

If the gorge is small, only one blast need be made. If the gorge is thirty feet wide and of considerable length, more than one blast will be needed. Use a charge of from three to six sticks tied together. This charge will shatter the ice for about twenty feet around it.

Get the explosive as low as possible between the cakes of ice without putting it in the water. If the gorge is narrow and short, the charge may be placed near the center and toward the front or down-stream end. If the gorge is large, remember that somewhere down in front and along the sides are certain key-cakes which lock the whole jam. When these cakes of ice are destroyed the whole gorge will move. Place the Powder so that these cakes will be shattered, then the main gorge will break up and float away. An electric blasting machine is the best means of firing the charges, but the firing may be done with fuse and caps. Have one person to light each different fuse and light them all at once at a signal.

A QUICK WAY TO KILL GROUNDHOGS

Groundhogs (called woodchucks in certain localities) often cause much damage, by digging holes into which horses step and by eating and knocking down clover, wheat and corn. They may be exterminated or driven away entirely with Atlas Farm Powder.

When the groundhog is in his burrow, explode a charge of Powder four or five feet back from the entrance. Prepare the charge in the usual way, using one stick of Farm Powder, with a cap and fuse cut four feet long. Put this charge as deep as the fuse will let you, and cave in the mouth of the hole. The force and fumes of the explosion will kill the animal.

LOOSENING LOGS, ETC., WITH EXPLOSIVES

Log piles, post piles, wood piles, coal and other material often freeze so tight that they can not be loosened with hand spikes or without excessive labor. Atlas Farm Powder will shake them loose without damaging the material.

Put a light charge somewhere down near the bottom of the pile. Get it alongside or underneath the "key"—that is, the log or post or place under the pile which would pull out to bring the whole thing down. Fire with fuse and cap or blasting machine.

EVIDENCE

"The cost in digging ordinary ditches with dynamite is less than half the cost of hand digging."

MICHIGAN EXPERIMENT STATION.

WHAT ATLAS FARM POWDER IS AND WHY IT IS SUPERIOR

Atlas Farm Powder and Atlas Powder 40 per cent. and 60 per cent. are improved forms of dynamite. They are made especially for farm purposes. They are high explosives. The difference between high explosives and other explosives lies in the rate at which the gases expand when the charges are fired.

Common black powder is a low explosive, and its gases expand comparatively slowly. If it is put off on a stone it will not crack the stone because the air yields quickly enough to accommodate the expanding gases. With high explosives put off in the same way (as in mud capping boulders), the gases expand so fast that the air cannot get out of the way, and the force is exerted against the material on which the explosive rests.

High explosives are fired by a shock of greater or less severity. There are many kinds of high explosives. They differ in the work they will do and in the strength of the shock required to fire them. Atlas Powder requires a severe shock to explode it, and Atlas Farm Powder requires an even greater shock. They are made this way so they will be safer.

Atlas Farm Powder and Atlas Powder 40 per cent. and 60 per cent. can be exploded only by a heavy shock. They never will go off of their own accord, and they stand considerable rough handling. To fire them properly requires a strong cap or electric fuze that gives both a heavy blow and intense heat.

Because of extra care in manufacture, Atlas Powders are always uniform in quality. They will keep perfectly for years. They never vary a pound in strength.

Most dynamites freeze at 40 to 50 degrees. In this condition they either will not explode at all, or will half burn and half explode, giving little force and creating poisonous gases entirely different from the gases of normal, proper explosions. Atlas Farm Powder will not freeze at temperatures several degrees lower than 32 degrees, and in practice it may be used right out in the field when the temperature is down to zero, without thawing. This saves a lot of trouble and prevents the waste of explosive by attempting to fire chilled dynamite.

There are low-freezing dynamites on the market but most of these give off noxious gases. Atlas Farm Powder does not give off such gas when exploded properly, because of its superior combination of chemicals.

Some kinds and grades of high explosives exert a shattering or pulverizing effect on anything which the expanding gases come in contact with. The dynamites that shatter, waste much of their energy, do not do the work well and cost more. Other kinds or grades heave and lift or split more than they shatter because their gases expand slower. The heaving or slow kinds are the ones best adapted to agricultural work. They loosen and powder the soil instead of caking and packing it or throwing it high in the air. Atlas Farm Powder has a heaving and cracking effect, with sufficient pulverizing action. It is the ideal farm explosive—made especially to meet the agricultural requirements.

HANDLING ATLAS FARM POWDER AND ATLAS POWDER

Atlas Farm Powder and Atlas Powder 40 per cent. and 60 per cent. were made especially so they would be safe to handle, and they are. As long as you exercise ordinary commonsense there is absolutely no danger of premature explosions.

Keep caps and electric fuzes away from the Powder; don't attempt to smoke when you are handling it; and keep it away from fire. Remember that it is an explosive and do not throw it about or handle it carelessly. Don't let the hot sun strike the sticks of Powder. It is much more easily exploded when warm.

All Atlas Powder should be stored in a dry place where the temperature does not get much higher than 80 degrees. Be careful that the *fuse* is kept cool and dry.

Blasting caps are much more sensitive to shock than Atlas Powder. Do not store them with the explosive if you can possibly avoid it. Don't let them fall, don't carry them around loose in your pocket, and don't set them where there is any chance of getting a shock. *Dampness weakens them.* A very little bit of heat from a fire will set them off. Electric fuzes must be handled the same as blasting caps.

TREATMENT FOR FREEZING AND CHILLING

Most high explosives lose their sensitiveness and do not properly explode when they are cold. They also give off poisonous gases. This condition is reached with all ordinary dynamites at a temperature of 45 or 50 degrees.

All grades of Atlas Powder contain an explosive that is hard to freeze. They do not lose sensitiveness even at the freezing point of water and they are often used at zero without thawing. When the temperature is below 30, however, it is best to keep the sticks under cover, or in a building where there is a slightly higher temperature. These Powders then may be loaded and exploded without warming, and the full strength of the explosive will be developed. You can tell whether a high explosive is chilled or not by its condition. If chilled it will be hard or have hard spots. If not chilled it will give when pressed.

Thawing is a very simple matter. Don't hold the sticks near a fire or stove, or immerse them in hot water, or blow live steam on them. When you do things like that with any explosive, you are taking chances.

There is just one way to thaw high explosives safely in a short time. It is easy, and there is never any need for attempting to do the work in any other way. Get two buckets, one larger than the other. Pour the big one half full of warm water. Have the other bucket dry, put the Powder in it, and set it inside the bucket where the water is. Then throw an old coat or horse blanket over them. The water should be no hotter than you can bear your hand in. In fifteen or twenty minutes the temperature of the Powder will be raised sufficiently to restore its full power. Do not have the buckets on a stove when you are thawing the Powder.

TOOLS USEFUL IN FARM BLASTING

The tools shown on the next page will save your time and make the use of explosives more effective by making it easy to put charges in the proper positions for best work.

The ordinary subsoil bar shown at "D" can be driven down two or three feet very quickly with a common sledge. If you have only a little blasting to do, an old crow-bar with one end sharp and the other end square would do.

A testing rod, which is nothing but a quarter-inch or three-eighths inch steel rod with a sharp point, is useful in locating roots and finding openings where the hole can go under stumps,stones,etc.

The most useful tool of all is the dirt auger. It is a special twist auger with a long leading point and with provision made for extension of the shaft. See "J" and "I" illustrated. The holes for all subsoiling work, ditching work, and most stumping work where the bar mentioned above is not used can be made to excellent advantage with this auger.

Where you want to bore into stumps the wood augers "G" and "H" are useful.

When very large jobs of blasting are to be done, it will pay to get a compressed air drilling machine. This is equipped with a small engine and air pump and the necessary drilling apparatus. With it you can put holes into the ground or down through roots, etc., at a speed of about six feet to the minute.

Tool "L," page 61, is the new Pugh machine wood-drilling auger.

Don't use an iron rod for tamping. A broom stick, or any stick about three-quarters of an inch in diameter, is superior and not dangerous.

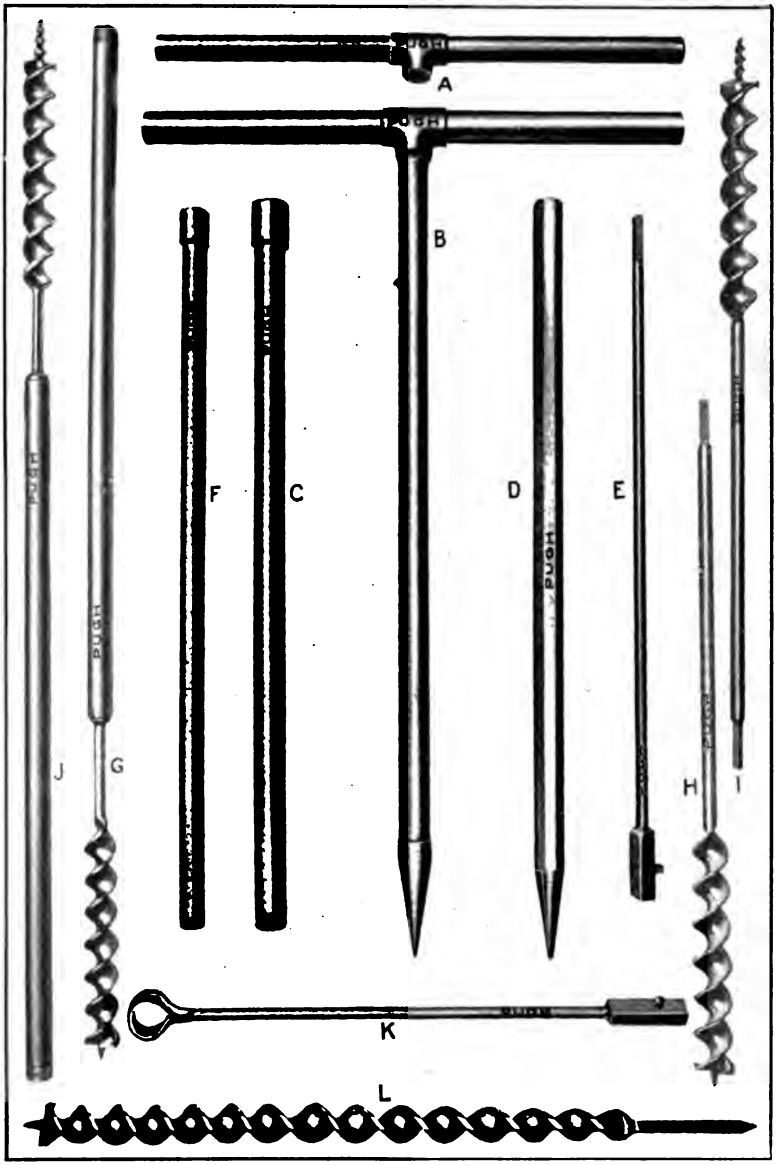
The Powder may be carried in a basket, or an even better way is to nail a basket handle on one of the 25-pound boxes in which the Powder comes, first emptying the box. In cold weather the Powder can be nested in this box in blankets or old cloth. Don't let it get wet, and don't let it lay in the hot sun.

The Atlas Electric Blasting Machine, one of which is shown on the following page, is extremely useful. These machines are made in various sizes. The No. 1 machine fires five charges at once. It is 4x5½x7½ inches and weighs six pounds. The No. 2 machine will fire ten charges at once. It measures 7x8x14 inches and weighs 20 pounds. The No. 3 machine will fire thirty charges at once. It is 7x10x18 inches and weighs 25 pounds. Directions for operating the blasting machine come with it. The blasting machine is the only means by which you can explode several charges simultaneously, (except by transmitted shock in ditching). It is the only reliable method of exploding charges under water.

EVIDENCE

"We have used explosives considerably in digging tree holes and in the heavier clay subsoils always have found the results highly useful in underdraining and in holding moisture."

T. J. W. TETIRICK, The C. V. Nurseries, Blackwell, Okla.



Atlas Electric Blasting Machine.

A—"T"pipe handle for augers "J", "G", "H" and "I".

B—New model bar for making holes for ditching, subsoiling, etc.

C—Extension shaft for "B".

D—Old model of subsoil bar.

E—Solid shaft extension for augers "H" and "I"

F—Pipe extension for shafts of "G"and "J" augers.

G—Pipe shaft wood auger.

H—Solid shaft wood auger.

I — Solid shaft dirt auger.

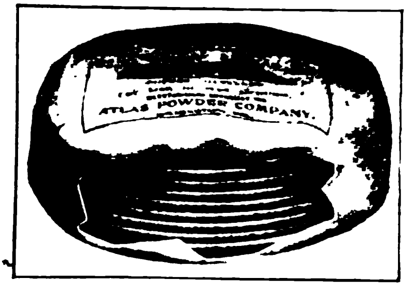
J — Pipe shaft dirt auger.

K—Old model shaft extension.

L—New machine drill wood auger.

These tools can be obtained from any hardware dealer. They are manufactured by Job T. Pugh, Philadelphia, Pa.

Coil of leading wire.

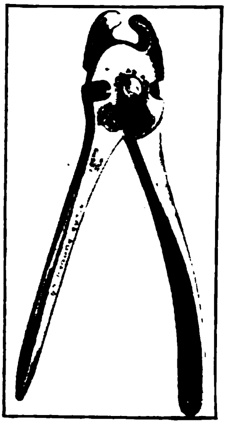


Roll of fuse.

Stick of Atlas Farm Powder.

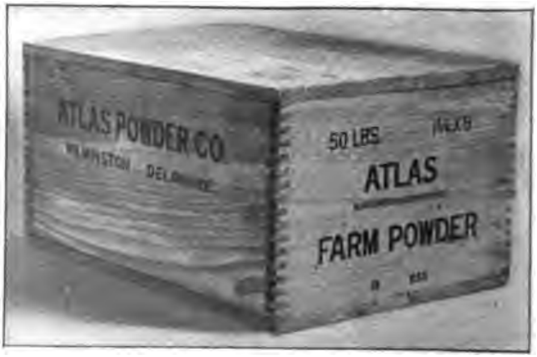
Spool of connecting wire.

Blasting caps (small box).



Cap Crimper.

Electric fuze carton



50-pound box of Atlas Farm Powder.

ATLAS BLASTING MATERIALS—MADE ESPECIALLY FOR FARM USE

You need some or all of the following Atlas goods for subsoiling, orchard blasting, ditching and other farm blasting.

ATLAS FARM POWDER—This is put up in sticks 1¼ inches in diameter by eight inches long. Each stick weighs about half a pound. A 50-pound box contains 98 to 100 sticks. These sticks are packed in 25- and 50-pound wooden boxes. This is the best explosive for all ordinary farm blasting.

ATLAS POWDER, 40 per cent. and 60 per cent.—This is put up in sticks the same size and almost the same weight as Atlas Farm Powder. A 50-pound box will contain from 95 to 100 sticks. This explosive is made for blasting hard rock, blowing big stumps in light sandy soil, and blasting big ditches in water-soaked ground. While it works a little better than Atlas Farm Powder for these purposes, yet the Farm Powder will do the same work, and the 40 per cent. or 60 per cent. Powder need not be bought unless you have much ditch or rock to blast.

ATLAS BLASTING CAPS—These are made in three different sizes for farm work—No. 6, No. 7, and No. 8. The No. 6 size is most popular and is made strong enough to explode Atlas Farm Powder and Atlas Powder. If you are not going to use them for some time, you will do well to buy the stronger caps. All caps are copper tubes, one to two inches long, open at one end. They contain a powerful explosive, sensitive to shock and heat and must be handled with the greatest care.

FUSE—This is put up in 100 ft. rolls. Beaver Brand is right for ordinary dry and damp work on farms,but for ditching, etc., where considerable water is encountered, Clover or Crescent Brand should be used. Keep in a dry, cool place and don't unroll when cold.

ELECTRIC FUZE—An electric fuze is a specially prepared "cap" into which is fastened wires that will give off heat when an electric current from a blasting machine is passed through them. Attached to the "cap" are two insulated copper wires, from four to thirty feet long as ordered. These fuzes must be used instead of blasting caps and fuse when you want to explode the charges with an electric machine. They are made in the same sizes as blasting caps with the same numbers. If your charges are to be entirely under water, get *special* waterproof electric fuzes that are *entirely* waterproof. Electric fuzes are packed 25 and 50 in a box.

ATLAS ELECTRIC BLASTING MACHINE—See description on page 60 and illustration on page 61.

WIRE NEEDED FOR ELECTRIC BLASTING—You will require "Leading Wire" to connect the blasting machines with the fuze wires. This should be 50 yards long for subsoil blasting, 100 yards long for stump blasting and 150 yards long for stone blasting. With the Single Leading Wire you must use two wires to the charges. Duplex Leading Wire has two insulated wires bound together within another insulating coat, and is easier to handle. "Connecting Wire" is light single wire. It is used to connect the end charges with the Leading Wire and to connect fuze wires that are too far apart to reach each other.

HOW TO HAVE BLASTING DONE IF YOU DO NOT WANT TO DO IT YOURSELF

If you do not want to conduct your own blasting operations, there are professional blasters who will do your work cheaply and efficiently. If your operation is large, it will pay you to get one of these men to superintend your work. He will save Powder and have the work done more quickly than an inexperienced man can do it. Write us for the name of the nearest Atlas blaster if you do not know one.

MEN WANTED TO LEARN BLASTING

As the use of explosives becomes more common for subsoiling, orchard work, and ditching, as well as for removing stumps and stones, there is an opportunity for hundreds of men to make money by becoming expert blasters.

Not every farmer knows how to handle explosives. Some of them do not care to learn. They will pay good wages to an experienced blaster, either by the day or on contract. If you are interested in learning agricultural blasting, we will be glad to take the matter up with you and tell you how you can get the training and experience. We furnish Atlas Blasters with letterheads, circulars, etc., and put them in touch with farmers who want to engage them.

HOW TO GET INFORMATION

In the foregoing pages we have given detailed information on the action of explosives in all farm work, and we have tried to tell just exactly how to prepare the charges and place and fire them to get the maximum efficiency.

If we have failed to make clear any points in connection with the benefits of using explosives for any purpose, or if we have failed to make clear to you exactly how to proceed with the use of Atlas Farm Powder, we shall appreciate it if you will write us fully.

If you have stumps or stones to remove, tell us how many and what kind. If you want to make ditches, give us an idea about how large and how long they must be and describe the conditions as well as you can. If you are interested in subsoiling, or in blasting for orchard work, give us details about the size of your orchard or field. We have experts in our office who will be delighted to take the matter up with you to any extent that you wish.

LETTER FOR INFORMATION.

USE THIS SHEET TO ASK QUESTIONS.

ATLAS POWDER COMPANY
WILMINGTON, DEL.

I want additional information on..

Tell me the following:..

....

....

....

....

....

....

....

....

....

Name..

Address..

71

EXPLOSIVES
and
BLASTING SUPPLIES

ATLAS POWDER COMPANY · *Wilmington, Delaware*

CATALOG OF PRODUCTS

INCLUDING
DYNAMITE, BLASTING POWDER
AND BLASTING SUPPLIES

ATLAS POWDER COMPANY
WILMINGTON, DEL.

A Nevada Copper Range Mine

TABLE OF CONTENTS

PAG

- Introductory
- Chap. I.—Explosives 1
- Chap. II.—What Explosives are Used For 1
- Chap. III.—How to Use Explosives 3
- Chap. IV.—Explosives and Blasting Supplies 4
  - Methods of Packing High Explosives 5
  - Comparative Densities of Atlas Explosives 5
  - Dynamite Explosives 53-6
    - Low Powders 6
    - Quarry Powders 6
    - Non-Freezing Explosives 6
    - Atlas Farm Powder 6
    - Non-Freezing Farm Powder 6
    - Stumping Special No. 2 L. F. 6
  - Blasting Powders 68-7
  - Blasting Supplies 71-9
    - Fuse 71, 7
    - Blasting Caps 7
    - Electric Blasting Caps 74, 7
    - Delay Electric Blasting Caps 76, 7
    - Squibs 78, 7
    - Cordeau-Bickford 8
    - Cap Crimpers, Leading and Connecting Wire 81, 8
    - Blasting Machines 82-8
    - Sureshot Shells, Tamping Bags, Blasting Paper 90-9
    - Rheostat and Galvanometer 9
    - Thawing Kettles 9
    - Storage of Explosives and Magazines 95, 9
- Chap. V.—How to Use Blasting Supplies 97-10
- Chap. VI.—Tests—Quality 10
- Chap. VII.—Service 10
- Chap. VIII. Handling, Storage, etc. 11
  - "Dont's" 11
  - Index (General) 11

A Blast that literally "Moved a Mountain" at Prince Rupert, B. C.

THE ATLAS PRODUCTS

OFFICES AND MANUFACTURING PLANT

OF THE

ATLAS POWDER COMPANY

GENERAL OFFICES

Wilmington, Delaware

BRANCH OFFICES

Allentown, Pa.
Birmingham, Ala.
Boston, Mass.
Charleston, W. Va.
Chicago, Ill.
Des Moines, Iowa
Houghton, Mich.
Joplin, Mo.
Kansas City, Mo.
Knoxville, Tenn.
McAlester, Okla.
Mexico City, Mexico
New Orleans, La.
New York City
Philadelphia, Pa.
Pittsburg, Kans.
Pittsburgh, Pa.
Pottsville, Pa.
St. Louis, Mo.
Wilkes-Barre, Pa.

MANUFACTURING PLANTS

DYNAMITE WORKS

Forcite Works, Landing, N. J.
Senter Works, Houghton, Mich.
Reynolds Works, Tamaqua, Pa.
Atlas Works, Webb City, Mo.
Tunnelton Works, Tunnelton, Pa.

BLASTING POWDER WORKS

Patterson Works, Patterson, Okla.
Chattanooga Works, Ooltewah, Tenn.
Fort Pitt Works, New Bethlehem, Pa.
Horrell Works, Hollidaysburg, Penna.
P. & K. Works, Pittsburg, Kan
Wolf Lake Works, Wolf Lake, Ill.

BLASTING CAP AND ELECTRIC BLASTING CAP WORKS

Tamaqua, Pa.

EXPERIMENTAL LABORATORIES

Tamaqua, Pa.

One of the Atlas Powder Company's Eleven Works

One of the Atlas Powder Company's many Tank Cars

THE ATLAS PRODUCTS

INTRODUCTORY

THE history of explosives dates back to ancient times. From the discovery of the first combustible mixture in the sixth century to the time of the invention of gunpowder in the fourteenth century, various crude forms of explosives were used.

It was not until the nineteenth century, however, that the first high explosives were produced.

In the remarkable progress made in the development and manufacture of explosives and in their application to industry, the Atlas Powder Company has played an important part.

With the knowledge and experience of several generations of makers of explosives to draw upon and after years of experimental and research work, this company has developed explosives of the highest type—explosives that are uniform and dependable—"A Proper Explosive for Every Blasting Requirement."

The Atlas Powder Company's fields of endeavor have multiplied. New products have been developed and marketed. Mechanical equipment has been made most complete. Officials and workers have worked as one in perfecting a smoothly running organization and all have shared in the Company's successes.

The following pages describe Atlas products, enumerate their multiple uses and explain accepted methods of using them. To the inexperienced blaster these pages will prove a source of valuable information and to those skilled in the use of explosives, this book should serve as a reliable guide and ready reference concerning explosives and blasting supplies for every blasting requirement.

CATALOG OF PRODUCTS

INCLUDING
DYNAMITE, BLASTING POWDER
AND BLASTING SUPPLIES

ATLAS POWDER COMPANY
WILMINGTON, DEL.

A Nevada Copper Range Mine

TABLE OF CONTENTS

PAG
Introductory . . . .
Chap. I.—Explosives 1
Chap. II.—What Explosives are Used For 1
Chap. III.—How to Use Explosives 3
Chap. IV.—Explosives and Blasting Supplies 4
  Methods of Packing High Explosives 5
  Comparative Densities of Atlas Explosives 5
  Dynamite Explosives 53-6
    Low Powders 6
    Quarry Powders 6
    Non-Freezing Explosives 6
    Atlas Farm Powder 6
    Non-Freezing Farm Powder 6
    Stumping Special No. 2 L. F. 6
  Blasting Powders 68-7
  Blasting Supplies 71-9
    Fuse 71, 7
    Blasting Caps 7
    Electric Blasting Caps 74, 7
    Delay Electric Blasting Caps 76, 7
    Squibs 78, 7
    Cordeau-Bickford 8
    Cap Crimpers, Leading and Connecting Wire 81, 8
    Blasting Machines 82-8
    Sureshot Shells, Tamping Bags, Blasting Paper 90-9
    Rheostat and Galvanometer 9
    Thawing Kettles 9
    Storage of Explosives and Magazines 95, 9
Chap. V.—How to Use Blasting Supplies 97-10
Chap. VI.—Tests—Quality 10
Chap. VII.—Service 10
Chap. VIII. Handling, Storage, etc. 11
  "Dont's" 11
  Index (General) 11

CHAPTER II

What Explosives are Used For

VARIOUS QUARRY OPERATIONS

Limestone, cement rock, trap rock, granite, slate, clay, marble, sandstone, etc.

RAILROADS - ROADS - TUNNELS - SHAFTS - CANALS - DITCHES

Various kinds of contract work.

AGRICULTURAL OPERATIONS

Loosening the subsoil, preparing tree beds, taking out stumps and boulders, providing drainage, ditching, etc.

MINING

Coal, metals, salt, gypsum, talc, etc.

SUBMARINE WORK

Removing underwater ledges of rock, destroying sunken vessels, deepening and widening channels, etc.

MISCELLANEOUS

Blasting ice jams, breaking log jams, breaking "scrapped" iron, loosening frozen material in railroad cars, loosening frozen ore heaps, excavating for cellars and foundations, razing buildings or walls in the path of fires, making holes for posts or poles, for straightening streams, draining lakes and swamps, land reclamation, extinguishing oil and gas well fires.

Blast at Vulcanite Portland Cement Co., Vulcanite, N. J.

Eagle Trap Rock Co., West Orange, N. J.

Note the uniformity of rock breakage

VARIOUS QUARRYING OPERATIONS

FROM the standpoint of the use of explosives there are two kinds of quarries: One, where the material is taken out in large or definite size, such as dimension stone for building purposes; and the other, where the material must be well broken for such use as ballast, concrete, or cement.

Dimension Stone

Both "A" and "B" Blasting powders are used extensively in this work. Low Freezing Extra Dynamite 15% or 20% also is employed in operations where this class of material is desired.

Horizontal or Snake Holes

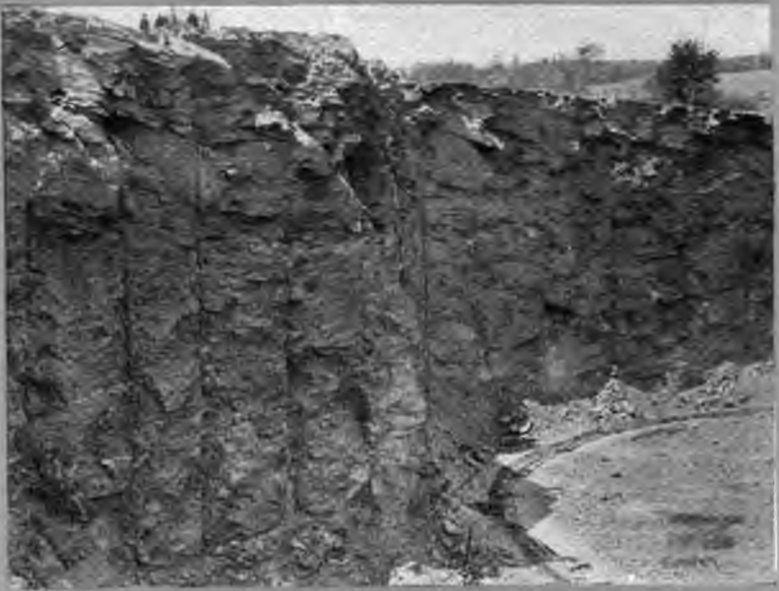
Where, because of inconvenience or for some other reason, it is not desired to drill perpendicular holes, "snake holing" is sometimes employed. In blasting in this manner the action of the powder is to lift and pull. It is usually customary to "spring" or "chamber" horizontal holes by firing a small charge of dynamite in the back of the holes which forms a pocket to hold the main charge. This operation should be repeated several times, or until the pocket is of sufficient size to hold the charge desired for the main blast.

Atlas Low Freezing Extra and Ammite 30% to 50% are commonly used for this class of work, provided the work is not too wet. Holes of this type may be connected and fired in the same manner that perpendicular holes are fired.

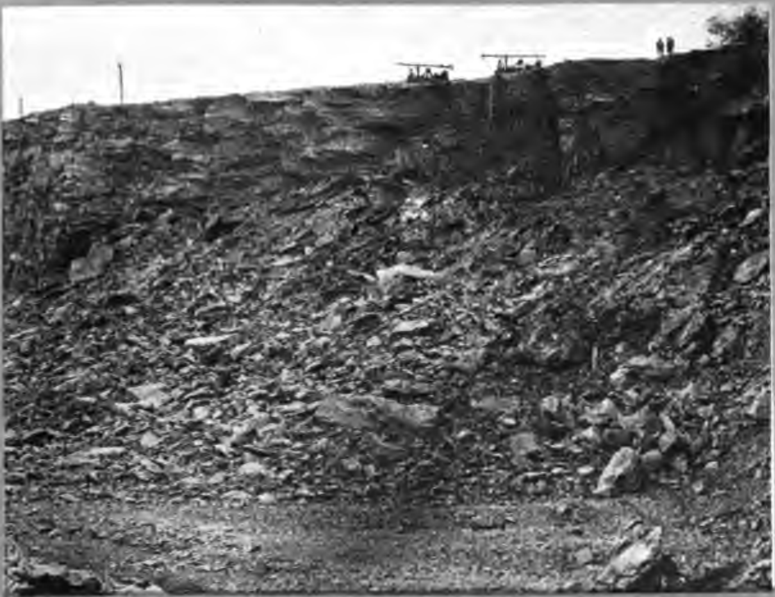
Buffer Shooting or Blanket Blasting

By Buffer Shooting is meant the loading and firing into the bank of stone previously blasted. This method, especially in a low bank where a steam shovel is used, piles the material blasted to a greater height and sometimes makes better digging for the shovel.

It is well to keep the powder charge low in the bore holes where the top is of loose formation so that when the bottom comes out the top will take care of itself.



Bath Portland Cement Co., Bath, Pa., before blast



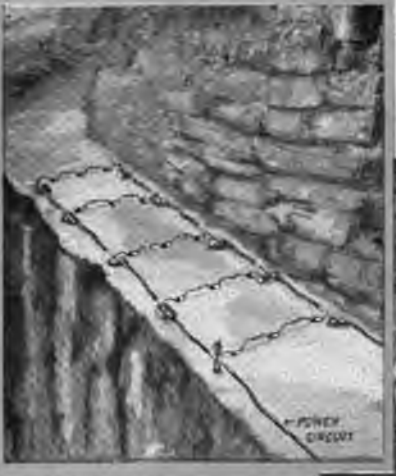
Same, after blast

Well-drill Holes

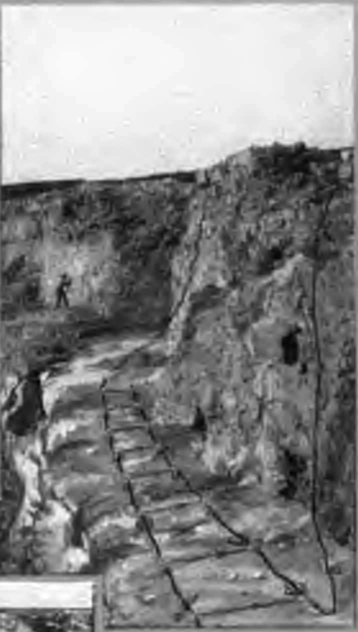
In this kind of blasting, placing the bore holes is important. If the burden is too great, dynamite will fail to do its work. If the burden is too light, waste of explosives or property damage may result. The object is, therefore, to have the charge properly balanced to give the breakage desired. If the material blasted is too large, a little lighter burden should be taken or heavier charges used on the next round of holes in an effort to secure better breakage. If this blast results in the material being broken too fine and thrown too far, then greater burden or lighter charges should be taken on the next blast. Measurements for the next line of bore holes should be taken before the blast, otherwise the measurements will be only approximate due to ragged condition of the face.

In deep holes it is customary to drill two to seven feet below the quarry floor in order to get all of the bottom. Many deep holes contain water which should be pumped and then loaded and fired quickly. For

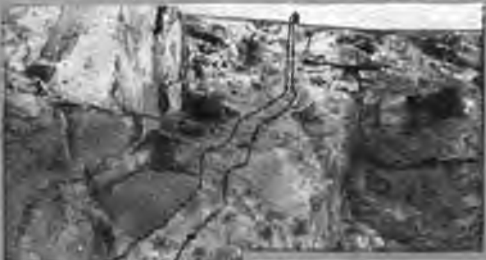
Pumping water from well-drill holes



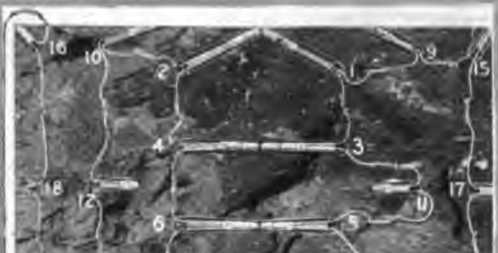
Parallel series connection



Parallel connection



Series connection



Tunnel or shaft blasting

this class of blasting, Atlas Ammite 30% to 50% or Atlas Low Freezing Extra 30% to 50% are in most general use. A combination of about one-third 50% in the bottom and two thirds 30% or 35% for the balance, has been found to be a very satisfactory charge. However, in some operations where severe water conditions exist, it is advisable to use either gelatin or nitroglycerin dynamite in the bottom. Two or more electric blasting caps should be distributed at equal distances in the powder charge in each bore hole and connected in single series if fired with a blasting machine. If fired by power or light circuit, they should be connected in parallel. (See illustrations on previous page.) The amount of tamping used in holes of this kind usually varies from 15 to 30 feet, depending upon conditions.

Piston drilling machine in operation

Shale Quarrying

Atlas R. R. P. or Low Freezing Extra powders 15% to 30% are recommended for this class of work. In some cases "B" Blasting powder is used successfully. If conditions are unusually severe, Ammite or higher grades of Low Freezing Extra, say 40% to 50%, may be advisable.

Stripping

In a general way various stripping operations require Atlas Ammite 35% to 50%, R. R. P., Low Freezing Extra 15% to 40% dynamite and sometimes "B" Blasting powder, depending on the class of the material blasted.

Atlas Powder removes stumps—

—and breaks boulders—

—and makes possible the early completion of a new road

RAILROAD CONSTRUCTION

Many different conditions are encountered in railroad construction. Atlas Ammite and Atlas L. F. Extra 40% are usually employed in this class of work, although very often R. R. P. or Blasting Powder is found more suitable and cheaper.

ROAD BUILDING AND MAINTENANCE

Practically the same conditions exist in this work as described under the previous heading "Railroad Construction."

SHAFT SINKING

Atlas Low Freezing Gelatin is well adapted to this class of work. It is plastic, water resisting and does not give off objectionable fumes. Blasting of this character should be accomplished electrically, delay electric blasting caps being used as detonators.

AGRICULTURAL OPERATIONS

In the chapter on "Explosives," page 66, a description of Atlas Farm Powder is given. The really wonderful results which have been achieved in farm work by the use of this powder could not be recounted in a single chapter of a publication of this kind. Because these results are so vital to agricultural prosperity, a separate book on the subject has been issued. This book is called, "Better Farming with Atlas Farm Powder (The Original Farm Powder)." It is enough to mention here some of the features discussed in this publication.

Explosives Do "A Thousand and One" Other Things—Explosives are "Portable Dynamos." They supply power in a most convenient form. They work where no other form of power can be applied. They do a thousand and one things cheaper and better than other agencies. No calculation of all the different ways in which they may be employed has ever been made. The list might grow to several thousands. Something new in the use of explosives comes to light almost every day.

In the book, "Better Farming with Atlas Farm Powder" a large number of conditions encountered in farm work in which explosives can be used successfully are described.

Tamping Coalite E L. F. charge in Bituminous Coal Mine

Tamping Coalite A L. F. charge preparatory to lifting the rock floor

ATLAS BLASTING POWDER FOR COAL

A large amount of Atlas Blasting Powder is used in breaking down bituminous coal. It explodes slowly in comparison with dynamite. It does not break the coal into small pieces. Still it has the required force. Blasting powder is made with grains of different sizes, the smaller granulations having the greater speed.

Bore Holes in Coal Mining

As a rule in coal mining, the bore holes vary from 1½ to 2 inches in diameter and from 3 to 8 feet in depth. The charge will fill from one-third to one-half the bore hole and will require from 2 to 7 pounds of powder. The weight of blasting powder varies to some extent with the size of the grain. The table given below, based upon a foot of blasting powder packed firmly in a bore hole, will serve a practical purpose:

Diameter of Hole	Weight of Powder Per Foot of Loaded Bore Hole
1½ inches	13 to 15 ozs.
1¾ inches	1 lb. 2 ozs. to 1 lb. 5 ozs.
2 inches	1 lb. 8 ozs. to 1 lb. 12 ozs.

Atlas Permissible Explosives in Coal Mining

A special form of explosive called "Permissible" is made for use in gassy and dusty coal mines. Every explosive so named has been passed upon by the United States Bureau of Mines and officially listed. The Atlas Powder Company has given a great deal of attention to manufacturing this form of explosive. The several kinds are described fully in Chapter IV on "Explosives," pages 60 and 61. Permissible explosives are easily handled. The detonation is relatively slow compared with that of other explosives of the dynamite class. If good judgment is used in the placing and charging of the bore holes, the coal may be broken down in almost any desired size. In every operation in coal mining where Atlas permissibles have been used they have given excellent results.

SALT MINING

Explosives are used to mine deposits of rock salt.

The Atlas Powder Company has made a careful investigation of the conditions of salt mining. As a result, Coalite B L. F. and Coalite E L. F. are recommended for this work.

Elsewhere in this catalogue attention has been given to the work for which explosives are used in industrial construction and contracting operations. Here are given examples of special forms of work for which explosives may be employed.

SUBMARINE WORK

At the bottom of rivers or harbors there may be ledges of rock or sunken ships or other obstructions that interfere with navigation. Explosives will remove these obstructions.

Under-water Ledges

In the case of a rocky ledge to be removed, an iron pipe is lowered from a staging or drill boat. Through the pipe the holes are drilled and charged. The weight and pressure of the water lessens the effect of explosives. Therefore, the holes should be drilled more closely together and the charges should be made heavier than in ordinary blasting. A waterproof electric blasting cap should be used. The holes are loaded by means of a "charger" (or "loading tube") and a long tamping stick. If wharves are near, the danger of damage to them from the blast is avoided by reducing the charge and putting very little space between the holes.

In forms of under-water obstruction, where it is not desirable to drill holes, a bundle of explosives tied together (in "Torpedo" style) is used. A diver fastens the bundle to the material to be blasted. A waterproof electric blasting cap is used for the priming and the firing is accomplished by electricity. Several such charges may be needed to do the work.

The explosive suitable to the usual form of deep water work is Gelatin Dynamite 40% to 60%, though often Nitroglycerin Dynamite is used to advantage. If the material to be blasted is unusually tough, Blasting Gelatin should be employed. These explosives are made so that they will work well under water.

They are packed in cartridges of different diameters from 1¼ up to 4 inches; and 8 to 24 inches in length, and protected by heavy paper wrappings.

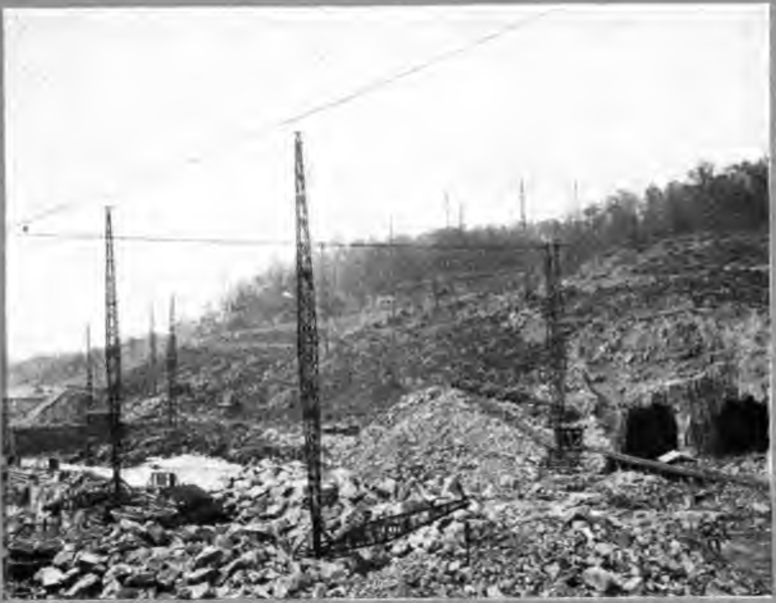
Sunken Vessels

Before blasting the wreck of a sunken vessel, it should be carefully examined by divers and the depth of water in which it lies, its condition and its position must be known before the explosive can be placed correctly.

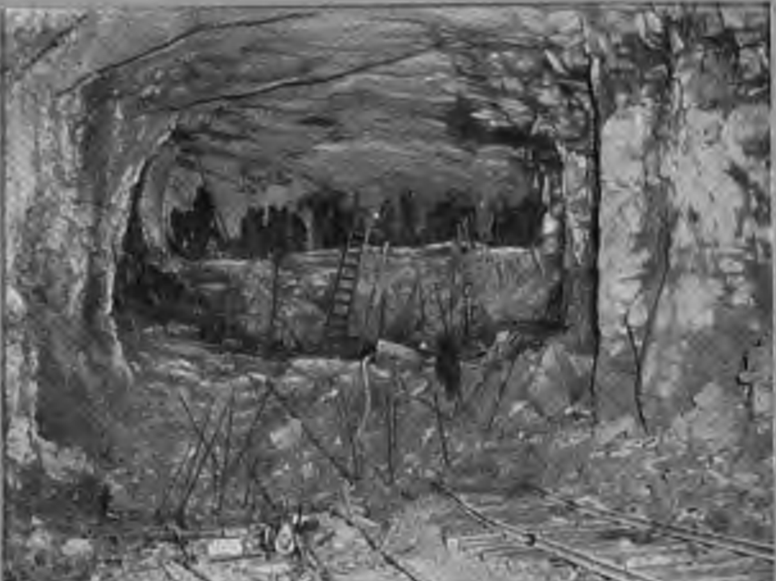
The masts of sunken vessels can be cut off by explosives. Cartridges fastened to a hoop are lowered over the mast to the desired position, and the charge fired electrically.

Pile Removing

Piles already driven may be cut off by the same method as that described above for the treatment of the masts. Gelatin Dynamite 40% to 60% should be used.



Tunnel construction at Whitney, N. C.



Interior of same tunnel showing benches

MISCELLANEOUS

Blasting Ice Jams

There are two methods of breaking up an ice jam, gorge or flow. In the first method the explosive charge is placed on the surface of the ice or in some hollow place or crevice, at the point where the formation seems to be the weakest. The charge may be 5 to 25 pounds (which would be contained in 10 to 50 cartridges of the 1¼ x 8 size).

In the second method, holes are cut through the ice in a semi-circular formation, the middle holes being down stream. Two to eight cartridges (1¼ x 8) are tied in a bundle. As many such bundles as are needed are lowered through the holes made in the ice. Cords fastened to the bundles hold them in position. The entire charge is located by this method on the under side of the ice. The cords should be "payed out" sufficiently to put the bundles well back under the ice. The leading wires which connect with the electric blasting caps should be long enough to reach to a point of safety for the "firer." Atlas L. F. Gelatin 40% is the proper explosive for this blasting.

Breaking Cakes of Ice

Tie together 3 or 4 cartridges of explosives. Prime one of them with a blasting cap and fuse. Tie the bundle to a block of wood and immediately after igniting the fuse, throw it upon the cake of ice, as near as possible to the center. The operation may require another and, perhaps, a larger charge. A nearby bridge may supply a position from which to drop the charge upon the floating ice cake.

Ammite or Atlas L. F. Extra Dynamite 40% to 60% is the explosive to use.

Opening a Log Jam

A jam of logs usually has a central point where one or more of the logs have become wedged. A fairly heavy charge of explosives, in the form of cartridges tied together, should be put at this central point. Atlas L. F. Nitroglycerin Dynamite 40% is the explosive and Atlas No. 6 Electric Blasting Cap the detonator to use. If no electric current is available, blasting cap and fuse may be employed. Care should be taken to have fuse sufficiently long to allow the blaster to reach a point of safety. By using explosives the work can be done much more quickly and with far less danger than with ordinary man-power methods.

7-ton casting reduced to scrap with 1½ lbs. of Atlas 60% Gelatin

Breaking up Old Castings and Boilers

When old boilers, machinery, castings, etc., are to be "scrapped," explosives are the best agency to use. For breaking a boiler the explosive should be removed from the cartridge and pressed in a train in the line of the proposed cut. The train of explosive should not be flattened or thinned out, but should be at least ⅞ of an inch thick. Well-tempered, stiff clay or mud should be used to cover the charge. The clay should be pressed firmly into place. Care should be taken not to break the train of the explosive. A blasting cap and fuse may be used for detonation. If done properly the operation will cut the boiler neatly.

A small charge placed against the side of a bolt head and covered with mud or clay and then fired, will take the head off.

L. F. Nitroglycerin Dynamite 40% to 60% is the explosive to use.

Castings can be broken easily by boring holes and filling them as well as any bolt hole or crevice with explosives. Many forms of old iron may be broken by placing the charge on top of them and firing by the "mud-cap" method.

Loosening Fertilizer in Warehouses

Using a two-inch rafting auger, bore holes from top of pile of fertilizer eight to ten feet deep leaving from two to three feet between bottom of holes and wood floor. Rarely are more than two or three charges placed at one time. Spacing between holes will depend upon condition of material. Holes should be loaded with one to four 1¼ x 8 cartridges of L. F. Extra Dynamite 20%, or Atlas Quarry Special No. 2 L. F. The charges should be fired electrically.

Loosening Frozen Material in Railroad Cars

When coal, ore, rock, cinders or any other material becomes frozen in a railroad car, to blast the material loose with explosives is a simple operation. The charge should be from ¼ to ½ a cartridge of Atlas L. F. Extra Dynamite 20% to 40%. It should be loaded in the crevices of the material. Either a blasting cap and fuse or an electric blasting cap may be used to fire the charge. If the car is constructed with a hopper dumping device, the hopper door should be opened and a hole bored from the bottom 10 or 12 inches into the material. The same amount of explosive (¼ to ½ a cartridge) should be used as described in the first method. By following the directions carefully the frozen mass can be entirely loosened without injury to the car and with a saving of several hours time.

Loosening Frozen Ore Piles

If a quantity of sand, rock, ore or other material, piled for storage becomes frozen so that it cannot be handled easily, the quickest and best way to break it up is to use explosives. The charge should be loaded in the crevices and detonated with a blasting cap and fuse or with an electric blasting cap. If the material is piled on a dock, a smaller charge should be used. (See the foregoing description of the method of Loosening Frozen Materials in Railroad Cars.) Atlas L. F. Extra Dynamite 20% to 40% or Ammite 30% is suitable for this work.

Atlas Explosives play an important part in every kind of construction work

Excavating for Cellars and Foundations

In making excavations for foundations, explosives frequently are necessary. The nearness of a roadway or a building need not prevent a contractor from considering this method. There is a way to guard against accident. Blasting mats made of heavy ropes are placed over the holes containing the charges and upon them heavy timbers are placed. (Railroad ties serve the purpose very well.) The charge should be small, a few cartridges of Atlas Ammite or Atlas L. F. Extra Dynamite 40% will be sufficient for the work.

The holes should be placed very carefully. The blasting mats will keep the rock and dirt from flying. But the shots must be so regulated that the detonation will not injure nearby foundations. The first round of holes should be shallow (2 or 3 feet deep) loaded lightly and well tamped. The effect of these shots will enable the blaster to determine how much deeper the holes and heavier the charges may be for the following shots.

Excavations

In every form of excavating in which explosives are used, it is certain there will be considerable variety in the kinds of material encountered. Hence, it is impossible to determine the proper kind of explosive to use until the material has been examined.

For general excavating work, Atlas Ammite 40% or Atlas L. F. Extra Dynamite 40% is best suited. Should the material be unusually hard a higher percentage should be used, but should it be found that 40% is too strong, then lower grades are recommended. Very often R. R. P. or blasting powder is suitable.

Tearing Down Buildings

Buildings, old foundations, stone, brick or concrete walls, can be quickly razed by the use of explosives. If a roadway or building is near such work, blasting mats or other protective covering should be used to prevent the material from flying.

In the case of a foundation, the holes should be drilled down in the wall from the top. They should be about 1 foot from the edge and only 8 to 12 inches deep. If needed, a second row of holes may be drilled. Use Ammite or L. F. Extra Dynamite, 30% to 40%, ¼ to ⅓ of a cartridge for each hole.

In the case of a wall 10 to 12 feet high, which is not near a roadway or other building, a larger charge may be used. The object is to rack and loosen the material. It then can be removed easily with pick and shovel. The holes are generally drilled horizontally into the side of the wall a foot or two above the ground and should be placed 4 to 6 feet apart. The charge should be from ½ to 1 cartridge depending on the depth of the hole and the thickness of the wall. The holes should be solidly tamped. The firing should be done electrically.

On steam shovel jobs Atlas Explosives save time and labor

In the Path of Fires

In certain emergencies it may be desirable to get buildings out of the way quickly. To clear combustible material from the path of a fire in a large city would be such an emergency. Explosives better than anything else can be used to meet this situation. To pull down a building for this purpose the charge of explosives should be placed against the strongest supports of the building. If they are broken down by the blast, most of the other parts of the building will collapse with them. Explosives of 40% strength or stronger will do this work.

Making Holes for Posts and Poles

To make a hole for a telegraph or a telephone pole, a hole about 2½ inches in diameter should be punched to within about 6 inches of the depth desired. Atlas L. F. Nitroglycerin Dynamite 60% should be used. The charge should be divided. The different parts of the charge should be fastened with wire or string to a stick (laths serve nicely) at intervals of 6 to 12 inches. A blasting cap, or an electric blasting cap, should be placed in the upper part of the charge. The other parts of the charge will detonate from the force of the primed charge. Loose dirt or stones should first be cleared from the sides of the holes, as such material might fall and lodge between the parts of the charge and cause some of them to misfire.

To make a hole for a fence post of ordinary size, a hole about 1½ inches in diameter should be punched to about the depth the post is to be set. A crowbar may be used for this purpose. Use Atlas Ammite or L. F. Extra Dynamite 30% to 40%. As to the amount of the charge, be guided by the condition of the soil. In the ordinary heavy soil, one half cartridge of the explosive will be sufficient. Do not tamp.

The blast will not loosen the ground in a sufficiently wide area to make it difficult to fix the pole or post firmly in place, if small charges are used. Digging out the top part of the hole (from 6 to 12 inches) and then punching the hole for the charge and blasting, will prevent the ground from being shaken up about the top of the hole.

Changing Stream Channels

Rivers, streams and creeks at times overflow, resulting in considerable damage to nearby farm land. Crops are ruined. Deposits of sand may spoil the soil. But the extent of the damage is increased by sharp turns in the channel caused by water-soaked wood, brush, tree roots and rock ledges.

Opening up a road on the mountain side in Scott County, Virginia

All of these obstructions can be removed, the water-course straightened and the channel deepened by blasting. The water-course itself can be made an attractive feature of the property. The nearby farm land can be rescued from the overflows and deposits of sand. For clearing the bed of the water-course use Atlas L. F. Gelatin 40%. For straightening and deepening the channel the following suggestions are made:

If material is dry and sandy, use Atlas L. F. Extra Dynamite 40% or Atlas Farm Powder; if material is wet clay, use Atlas L. F. Nitroglycerin Dynamite 60%. The blasting method of accomplishing such improvements will be found both economical and effective.

Making Small Lakes or Ponds

When it is desired to make a small lake or pond for fish or for ice, the earth can be blasted out. It would not be advisable to try to make the entire excavation with explosives except for a small pond because some of the earth would fall back into the excavation. But the material may be loosened by the blasting so that its removal by scrapers will be made an easy task. For excavating for this purpose use Atlas Ammite, L. F. Extra Dynamite 30% or Farm Powder. The entire work can be done in far less time and with a saving in cost by the use of explosives.

Land Reclamation

Many thousands of acres of government land have been reclaimed. Many additional thousands of acres will be reclaimed.

Arid, "cut-over" and swampy acres, if treated by scientific methods, can be made fertile.

Here is where explosives will play a large part. The treatment of arid land calls for irrigation. This means the building of dams and canals in which blasting will be necessary. To clear "cut-over" territory requires the blasting of stumps. The problem in the case of swamps is one of drainage. Ditches and drainage canals are needed. In this work explosives give the quickest and best help. Valuable details as to the use of explosives for this kind of work are given in the book, "Better Farming with Atlas Farm Powder," which will be mailed to anyone asking for it.

Extinguishing Oil and Gas Well Fires

Gas and oil well fires are economically and successfully extinguished through the use of explosives. Atlas L. F. Gelatin Dynamite, Atlas Blasting Gelatin L. F. or Atlas Oil Well Explosives L. F. 100% should be used. A charge proportionate to the volume of the flame should be placed in a container of wood or some other material of such a nature that it would cause no damage when the contents explode and which is amply protected with asbestos covering. This container is primed and connected for electrical firing, the leading wires being covered with asbestos or other fire-proof insulation. A flexible cable is secured some distance away from the well and laid around the flame. The charge is fastened securely to this cable at a point that will suspend it in the center of the flame when the cable is pulled taut. The charge must be fired at the precise instant it reaches the proper point in the flame. The force of the explosion temporarily stops the flow of the gas, breaks the contact and thus extinguishes the flame.

Burning gas well that was extinguished with explosives

Bethlehem Mines Corporation, Cornwall, Pa.

Where 72 holes 30 feet 6 inches deep loaded with Atlas Explosives were shot in one blast.

CHAPTER III

How to Use Explosives

IF ALL earth were "just ground" and if all ground were alike, blasting problems would be few.

But, every foot of earth or rock in which one may blast may be different from every other foot. The differences are sometimes very great indeed. Blasting problems, therefore, are not few. They are without number. But knowledge grows. Conditions in which explosives are to be used can be analyzed. They can be compared with other conditions. Gradually, out of actual experience in the field, certain conditions, and sets of conditions, can be understood. Some of them, at least, can be classified as more or less typical.

There are many instances in this catalogue where a definite recommendation is made regarding the kind of explosive to use. Usually the condition described is a typical one.

Every recommendation in this catalogue is offered with the understanding that, in any particular case, factors differing from those named, may enter and alter the condition.

The user of Atlas Explosives is invited to consult with the Company's Service Division (see Chapter VII on "Service") before undertaking any particular blasting work.

In planning a blast one of the chief factors is that of explosives—the kind and the amount. It will be useful, therefore, to know how one pound of an explosive of a given strength will compare with a pound of a different strength. Such a comparison can be made by the aid of the following table:

COMPARING DIFFERENT STRENGTHS

One pound of 60% equals:						
	1.10 lb. of 50%	1.18 lb. of 45%	1.27 lb. of 40%	1.35 lb. of 35%	1.49 lb. of 30%	1.61 lb. of 25%
	1.73 lb. of 20%	1.87 lb. of 15%	2.09 lb. of 10%			

It will be seen, for example, that one pound of 60% Nitroglycerin Dynamite is equal in strength to nearly one and a half pounds of 30%

strength. Also that two and eight-hundredths pounds of the 10% strength is the equivalent of one pound of the 60% strength. This set of ratios also may be used in comparing the strength of one cartridge of any given strength with the same size of cartridge of any other given strength of the same explosive.

HOW TO FIGURE TONNAGE BLASTED

Starting with the weight of a cubic foot of the rock, the tonnage to be blasted can be approximated. For example, a cubic foot of solid limestone has been found to weigh about 168 pounds. If, for example, the length of the rock mass to be blasted is 200 feet, the width 25 feet and the height 80 feet, the tonnage can be calculated by multiplying the three dimensions. The result is 400,000 cubic feet. Multiplying this by 168 and dividing the result by 2,000 (pounds in a ton) gives the weight of the mass in tons, namely, 33,600 tons.

The weight of a cubic foot of nearly every kind of material in which explosives are used, from gravel to gold, is known.

If the user will write to the Atlas Service Division, telling the kind of material in which he is working, he will be given the weight of a cubic foot of that material. It will be understood, however, that in some materials, such as the ores, the variation in the weight is so great that it is better to use the cubic yard as a basis of calculation.

The tables showing the results of blasts actually made, which appear elsewhere in this Chapter, give the amount of material broken down per pound of explosive used. The figures in this column vary greatly. In some cases the data supplied explains the results. The result of the shot depends on the placing of the bore holes and the kind and grade of explosives used.

Time, Labor and Money can be Saved

A well-known authority on the subject of explosives has said:

"If you are using more than a third of a pound of explosives per ton of stone taken from your quarry, there is room for improvement."

While this applies particularly to quarrying, similar statements with the ratio made appropriate to that field could be made regarding each field in which explosives are used.

THE IMPORTANCE OF TAMPING

The gas which is created when an explosive is detonated is bound to get out. If the explosive is detonated in a confined place, the gas will break down the walls. If there is a crack or other opening, it will escape through that.

Tamping is most important. If the powder charge is not properly tamped, the gas will escape, a certain portion of energy will be wasted and what is equally objectionable in underground work, large volumes of poisonous gas will escape into the mine where men are working.

Tamping Material

Clay or sand makes the best tamping material, but if these are not obtainable ordinary soil, brick dust, stone dust, etc., will answer.

Care should be taken that tamping is free from pieces of rock or other hard substances, otherwise fuse or wires may be damaged.

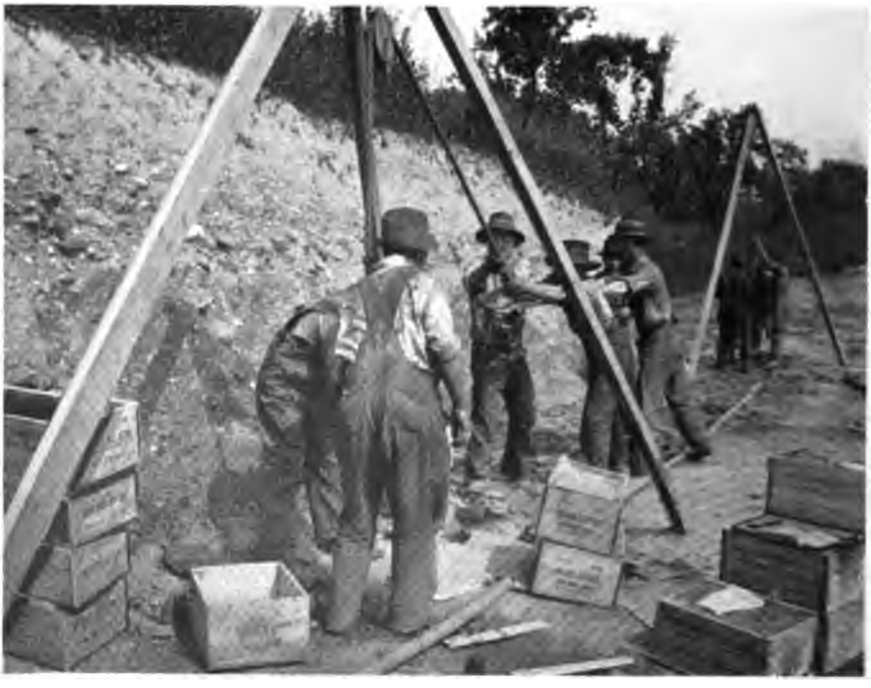
Where horizontal or upward holes are drilled as in mine or tunnel work, the tamping material should be placed in Sureshot Shells, otherwise tamping will be tedious work.

Loading well-drill holes in zero weather with Atlas Ammite—the explosive that cannot freeze

How to Tamp

For tamping piston drill holes a light wooden pole should be used. For well-drill holes a block of wood 3 or 4 feet in length and rounded to fit into the hole, with a rope attached for lowering and raising, should be used. It now is common practice, except in cases where the powder charge comes up very high, to merely pour the tamping material into the well-drill hole as it packs sufficiently from its own weight.

The tamping stick may be weighted by drilling holes in it and filling the holes with molten lead, after which the holes should be plugged with wood to prevent the lead from coming out. The extra weight is of value when the tamping is done in water.



Tamping well-drill holes

Do Not Use Iron

Nothing but a wooden pole or block should be used in tamping. It may be a temptation to use a drill bit or iron bar that may be handy. **BUT DON'T DO IT. DON'T USE ANYTHING CONTAINING METAL.**

After a charge has been put in place in small drill holes 2 or 3 inches of the tamping material should be pressed carefully down on the charge. This tamping should be done very gently. Carelessness might cause a premature explosion. For the next few inches of the space the material may be packed in a little more firmly. After about 5 inches of tamping has been accomplished that remaining can be done with a little more power. It is not safe, however, to use any force stronger than hand power.

The fuse, or the wires of the electric blasting cap or of the electric igniter, should be watched carefully to see that they are not injured during the tamping process.

Broken Charges

In some rock formations, what is known as "broken charges" may be employed. For example, should a clay seam appear in the bank of stone to be shot, it would not be advisable to load that portion of the hole with explosives. The charge should be divided, with some placed a distance below and some above, while the clay seam is filled only with tamping material. Care should be taken, however, to have the necessary electric blasting cap in each part of the charge of explosives.

Note:—We have not used the word "stemming" in this article. It means the material used for tamping and is so used in the publications issued by the Government Bureau of Mines.

The importance of proper tamping is emphasized by the Bureau of Mines in Bulletin No. 17, which says:

"Every explosive, when exploded, exerts pressure in every direction. When laid on top of rock and exploded, gun powder and other low explosives do not affect the rock because they explode so slowly that the gases formed can lift the air above them and escape; but dynamite, fulminate of mercury, and other high explosives, if laid upon brittle or soft rock and detonated, may shatter it, because they explode so quickly that the gases formed cannot lift the large volume of air which confines them without pressing back forcibly against the rock. This confinement by air is not, however, close enough to give the best result with an explosive. By boring a hole in rock and tamping the explosive firmly in it, blackpowder and other low explosives may be made to break the rock, or a much less quantity of high explosives will break the rock than is required to break it when laid upon it. Confining an explosive is the cheapest and best way to use it."

CHAMBERING AND SQUIBBING

The process, also called "springing," is to make a hole larger at the bottom by using a small charge of explosive.

The advantages of springing the holes in a large blast where the material blasted will permit of its being done successfully, are these: First, it makes possible the concentration of the charge at the place where the burden is the greatest. Second, it distributes the entire charge in fewer holes and thus effects a saving in the drilling cost.

From one to twenty-five pounds of explosive, possibly more, may be required for the springing charges of a bore hole. The amount of explosive to use must be estimated according to the nature of the work, the first shot having the lightest charge and the charge increasing with each successive shot.

The rule is to use a series of shots to spring the hole. In such a case the amount of explosives is gradually increased with each shot.

Atlas L. F. Extra Dynamite 30% to 40% strength is recommended.

Do not start to charge a hole immediately after a springing shot has been fired in it. Wait until the hole has cooled. Otherwise the heat may cause a premature explosion.

After a hole has been sprung it is important to see that the cavity is completely filled with the charge. If blasting powder in bulk form is used, a thin tamping stick may be put in the hole and gently raised and lowered while the powder is being filled in. This will spread the powder out and fill the hole better. If any grains of powder have been spilled at the mouth of the hole, they should be carefully brushed into it.

MUD-CAPPING

This method is sometimes called "Doby Shooting," "Blistering" or "Bull-dozing."

In mud-capping, no hole is drilled. The explosive is placed on top of the boulder and near the centre of the top. If there is a crevice or hollow space, the explosive should be placed in it. The size of the charge, of course, will depend upon the size of the boulder. The cartridges should be slit open, so that they may be pressed closely together. An explosive which will deliver a quick and shattering blow is best for this work. Atlas L. F. Nitroglycerin Dynamite 40% to 60% strength will give the desired results, although Atlas L. F. Extra Dynamite of the same strength is often used successfully. The primer should be put in the centre of the charge. The charge should then be covered over with stiff mud or clay. (This is the mud-capping which gives the name to this method of blasting.) The mud-cap should be packed firmly in place.

BLOCK-HOLING

In block-holing, a hole is drilled in the boulder toward its centre. Usually a one-inch diameter hole will be large enough. The explosive should be taken out of the cartridges and the proper amount put into the hole, the hole should then be tamped solidly up to the mouth. In some instances a large boulder will require more than one charge. The shot will not be a success unless the hole is properly tamped. Atlas L. F. Extra Dynamite, 20% to 40% strength, should be used.

USING MIXED CHARGES

Many operators dislike to use more than one grade of explosive for the handling of the explosive is somewhat easier when only one grade is used. On the other hand, far better results frequently are obtained when the hole is loaded with a mixed charge.

This has been done in tunneling and quarrying and in general mining. The practice is to put the stronger explosive in the bottom or back of the hole and make up the rest of the charge with a weaker one.

In very hard and tough rock, or where (as in the face of a quarry) there may be an especially heavy burden at the bottom, the combination shot may be employed successfully. It also may be used when it is the aim to throw out the material with good breakage and pile it conveniently for shoveling. The cost of explosives per ton of material broken will be lessened by employing this method.

It will be found that some of the shots included in the tables given on pages 47 and 48 were made with mixed charges. The results can be noted in the column showing the amount of material broken down per pound of explosives used.

MISFIRES

When a charge in a hole fails to detonate, usually it means the cost of drilling another hole. It also means the danger of an accidental discharge of the unexploded material.

Means of preventing misfires are: Careful priming, tamping, inspecting and testing the blasting circuit with the galvanometer and rheostat, and the use of sufficient electric current.

Operating a power drill in underground mining

Table showing the results secured in actual quarrying work. These figures will be found valuable as a guide for estimating purposes.

QUARRYING

Test No.	Kind of Material	Height of Face	No. of Holes	Average Depth of Holes	Average Distance from Face	Average Distance Apart	Kind of Explosives	Total lbs. of Explosives	Wgt. of Material per cu.ft.	Tons Blasted per lb. of Explosives
1	Cement Rock	67′	23	72′	18′	16′	L. F. Extra 50%, 40%, 30%.....	12,500	165 lbs.	3.2
2	Cement Rock	145′	21	147′	25′	16′	L. F. Extra 50%, 30%..........	28,064	165 "	3.57
3	Limestone...	32′	3	33′	18′	15′	L. F. Extra 40%.	450	160 "	5.5
4	Cement Rock	44′	5	51′	21′	17′	L. F. Extra 50%, 40%..........	1,790	165 "	3.35
5	Limestone...	25′	2	24′	18′	10′	L. F. N G 40%..	200	168 "	5.4
6	Trap Rock...	78′	6	74′	14′	17′	L. F. N G 60%, 30%..........	2,500	170 "	3.3
7	Limestone...	46′	6	43′	20′	18′	L. F. Extra 50%, 30% and FFF Blasting Powder	1,975	160 "	3.35
8	Limestone...	22′	81	21′	14′	12′	L. F. Extra 40%.	7,200	160 "	1.455*
9	Cement Rock	20′	10	20′	10′	7′	Rendite Stumping Powder....	300	160 "	2.8
10	Limestone...	49′	8	50′	30′	18′	L. F. Extra 50%, 30%.........	2,000	170 "	5

* Short Spacing and light burden but well-broken.

Table showing the results secured in actual quarrying work. These figures will be found valuable as a guide for estimating purposes.

QUARRYING

Test No.	Kind of Material	Height of Face	No. of Holes	Average Depth of Holes	Average Distance from Face	Average Distance Apart	Kind of Explosives	Total lbs. of Explosives	Wgt. of Material per cu. ft.	Tons Blasted per lb. of Explosives
11	Hard Blue Shale.....	47′	8	18′	18′	15′	L. F. Extra 40% and Quarry Powder.......	1,700	165 lbs.	3
12	Limestone...	41′	13	45′	16′	16′	L. F. Extra 60%, 50%, 30%.....	5,900	165 "	2.002
13	Limestone...	44′	5	50′	20′	18′	L. F. Extra 50%, 30%..........	1,250	170 "	6.8
14	Limestone...	36′	5	44′	32′	16′	N G 60%, 40% R. R. P.......	1,650	165 "	4.8
15	Cement Rock	53′	26	53′	23′	18′	L. F. Extra 50%, 30%..........	7,950	165 "	5.033
16	Limestone...	36′	3	38′	19′	15′	L. F. Extra 40% R. R. P.......	1,325	170 "	5.35
17	Trap Rock...	200′	28	136′	43½′	20½′	L. F. Gel. 60%, 40%..........	37,500	180 "	8.14*
18	Cement Rock	150′	15	150′	26′	17′	L. F. Extra 50%, 30%..........	21,000	165 "	2.86
19	Trap Rock...	..	..	..	..	..	L. F. Extra 50%, L. F. Gel. 50%.	23,250	..	6.45

* Heavy burden, breakage slight.

THE ATLAS PRODUCTS

CHAPTER IV

Explosives and Blasting Supplies

As a manufacturer of Explosives and Blasting Supplies the Atlas Powder Company, in a large way, has a three-fold policy:

First, it must keep its product up to that high standard upon which the reputation of Atlas Explosives has been built.

Second, through continuous research and experiment, it is constantly seeking to improve its product.

Third, it is seeking to meet every new need with a commodity suited to that need.

Following the list of Atlas Explosives and Blasting Supplies (enumerated below) is a description of each individual item. How they are used is explained in Chapter II, "What Explosives are Used For."

EXPLOSIVES

Nitroglycerin Dynamite—25% to 60% strength, Low freezing.

Extra Dynamite—15% to 60% strength, Low freezing.

Gelatin Dynamite—25% to 80% strength, Low freezing, packed in white paper cartridges.

Extra Gelatin Dynamite—40% to 90% strength, Low freezing, packed in white paper cartridges.

Blasting Gelatin—100% strength, Low freezing.

Oil Well Explosive—100% strength, 80% strength, Low freezing.

Coalite—(10 grades), 9 Low freezing and one Non-freezing. A Permissible Explosive, packed in white paper cartridges.

Low Powders—(four grades), 5% to 20% strength, Low freezing.

Quarry Powders—(three grades), Low freezing.

Ammite—(six grades), 30% to 75% strength, Non-freezing.

Atlas Farm Powder—The Original Farm Powder, The Safest Explosive.

Atlas Non-Freezing Farm Powder—Non-freezing.

Atlas Stumping Special No. 2 L. F.—Very low freezing.

Blasting Powder—(two grades), "A" Blasting—6 granulation sizes, "B" Blasting—8 granulation sizes.

Fire Works Powder—(four grades), "A" or "A" Dust, Fine Meal, Coarse Meal (or Meal D) and "A" Special.

Squib Powders—(two grades), FFFG, Special.

Black Sporting Powders.

Smokeless Sporting Powders.

BLASTING SUPPLIES

Safety Fuse—Cotton, Single Tape, Double Tape, Triple Tape, Beaver, Charter Oak, Clover, Anchor, Crescent, Reliable.

Blasting Caps—(Detonators), No. 6, No. 8.

Electric Blasting Caps—(Detonators), No. 6, No. 8.

Delay Electric Blasting Caps—For 5 different delays.

Delay Electric Igniters—For 5 different delays.

Powell Squibs—Rocket No. 1, Gas No. 2, Superior Safety Gas.

D. and B. Squibs—No. 1, No. 2, No. 3.

Blue Label and Red Cross Squibs—Sulphur, Gas.

Electric Squibs—5 lengths of copper wire, 3 lengths of iron wire.

Cordeau-Bickford—No. 6 plain, No. 6 countered, also, Cordeau Slitters, Cordeau Crimpers, Straight Unions, Special Unions, Couplings.

Cap Crimpers—No. 4, groove crimp; No. 5, broad jaw crimp.

Cap Carriers—For holding blasting caps.

Leading Wire—No. 14 B. & S. Gauge, Single, Duplex.

Connecting Wire—No. 20 and No. 21 B. & S. Gauge, 1 lb. spools, 2 lb. spools.

Blasting Machines—No. 0, No. 1, No. 2, No. 3, No. 5 and No. 6; also Mason Turbine.

Sureshot Blasting Shells—3 standard sizes (other sizes to order).

Tamping Bags—Nine sizes.

Blasting Paper—Supplied in rolls.

Kapseal—1 lb. tin cans.

Rheostat—Capacity 5 to 150 electric blasting caps.

Galvanometer—For testing blasting circuits.

Thawing Kettles—No. 1 (cap. 30 lbs.); No. 2 (cap. 60 lbs.).

Storage Magazines—Portable Dynamite Magazine No. 63 (three sizes), Portable Iron Powder Magazine No. 31 (six sizes), Storage Magazine (10 sizes).

METHODS OF PACKING HIGH EXPLOSIVES

All Atlas Dynamites except R. R. P. are packed in cylindrical containers, called shells, made of paraffine paper. Cartridge shells of explosives to be used in very wet work are given an extra water-resisting coating.

Any standard size cartridge can be furnished, but the size most commonly used is 1¼″ x 8″, excepting four- and five-inch diameters for well-drill holes.

Transportation regulations do not permit the shipment of dynamite containing more than 10% of Nitroglycerin in cartridges larger than 5 inches in diameter and 8 inches in length. If longer ones are desired two or more are enclosed in another shell. Gelatin containing more than 10% may be shipped in cartridges longer than 8 inches in length.

Atlas R. R. P. is put up in bags containing 12½ pounds each, and shipped in cases holding 4 bags, or 50 pounds. Atlas F and Ammite grades may also be packed in bags containing 12½ pounds.

There are five different methods of packing Atlas Dynamite explosives for shipment. Each order should specify the kind of packing desired.

Case 1. Contains 50 pounds (net) of explosives in cartridges or in 4–12½ pound bags of R. R. P., F or Ammite.

Case 2. Contains 50 pounds (net) of explosives, in cartridges packed in 4–12½ pound cartons, 5–10 pound cartons or 10–5 pound cartons.

Case 3. Contains 25 pounds (net) of explosives in cartridges.

Case 4. Contains 25 pounds (net) of explosives in cartridges, packed in 2–12½ pound cartons, 4–6¼ pound cartons or 5–5 pound cartons.

Case 5. Contains 10 pounds (net) of explosives in cartridges.

All cases are wood, made of seasoned lumber and comply in every way to the specifications of the American Railway Association and the Interstate Commerce Commission.

Note: While all Atlas Dynamites are packed in one or more of these methods, not *every* grade is packed in *all* five ways.

DENSITIES OF EXPLOSIVES

The *minimum* number of cartridges of each size, and of each explosive, packed in a 50 lb. case. Cases sometimes contain as much as 10% more than the numbers of cartridges given.

KIND AND GRADE OF EXPLOSIVE	SIZE OF CARTRIDGES AND NUMBER TO EACH 50 lb. CASE								
	⅞ x 8"	1 x 8"	1⅛ x 8"	1¼ x 8"	1½ x 8"	1¾ x 8"	2 x 8"	4 x 8"	5 x 8"
Nitroglycerin Dynamite Extra Dynamite	208	160	128	105	72	54	41	11	7
Gelatin and Extra Gelatin Dynamite 80% and above Blasting Gelatin	188	146	117	96	64	49	37	10	7
Gelatin and Extra Gelatin Dynamite 60 and 75%	183	140	113	91	62	46	35	9	6
Gelatin and Extra Gelatin Dynamite below 60%	175	135	109	88	60	44	33	8	6
Coalite A L. F.	260	211	160	133	96	72	53	..	..
B L. F.	285	228	190	155	105	77	58	..	..
C L. F. and E L. F.	247	202	152	128	92	69	51	..	..
D L. F.	272	215	173	144	101	75	57	..	..
F L. F.	...	192	144	123	88	66	50	..	..
G L. F.	275	217	175	145	102	75	57	..	..
H L. F and L N.	233	180	143	117	81	60	45	..	..
No. 4 L. F.	260	211	160	133	96	72	53	..	..
Quarry Powder L. F. Quarry Extra L. F.	208	160	128	105	72	54	41	11	7
Quarry Special No. 2 L. F.	285	228	190	155	105	77	58	15	10
Low Powders F, FF, FFF	195	153	121	100	68	53	39	10	7
Ammite 30, 35, 40 and 50%	...	167	135	109	75	55	42	11	7
Ammite 60 and 75%	233	180	143	117	81	60	45	11	7
Farm Powder	...	...	...	105	...	..	..	..	..
N. F. Farm Powder	...	...	...	109	...	..	..	..	..
Stumping Special No. 2 L. F.	285	228	190	155	105	77	58	15	..

Nitroglycerin Dynamite

25% to 60% Strength
LOW FREEZING

NITROGLYCERIN or "Straight" Dynamite is a powerful, quick-acting high explosive. Compared grade for grade with other kinds of explosives, it acts with greater speed.

It will shatter and splinter and should, therefore, be used wherever this result is desired. It is very effective for blasting boulders by mud-capping, for breaking old machinery and castings, and for "shooting" ditches in wet ground. It will partially resist water, but if permitted to remain in a wet place for any great length of time, will lose a part of its strength. The fumes given off on detonation by grades weaker than 50% are unobjectionable even when the work is not well ventilated.

Nitroglycerin Dynamite is sometimes called the original dynamite, as the first form of this explosive was a crude combination of nitroglycerin and a spongy-like earth, that possessed great absorbent qualities.

Great improvements have been made since in the manufacture of the original form of nitroglycerin dynamite. The absorbent earth has given way to other elements, and chemicals that make the explosive more efficient, are now employed in place of the absorbent earth.

Extra Dynamite

15% to 60% Strength

LOW FREEZING

This is one of the most serviceable all-around explosives manufactured. In Extra Dynamite, ammonium nitrate partly takes the place of nitroglycerin. While the strength of the ammonium nitrate dynamite is equal to that of the corresponding grade of nitroglycerin dynamite, the speed of detonation is slower. This produces more of a heaving and rending than a shattering effect.

Extra Dynamite is one of the safest explosives to handle and use. It requires a severe shock to detonate it. Consequently, the risk from accidental explosion is slight.

When detonated the fumes given off are not sufficient to prove objectionable or obnoxious except in improperly ventilated mines.

It is well adapted to quarry and construction work, highway and railroad blasting, and to mining operations. It will give good results wherever conditions are not very wet.

The development of Low Freezing Extra Dynamite was an important step in the progress of the explosive industry, for this explosive possesses many advantages over nitroglycerin dynamite.

Underground work in the mining of lead

Gelatin Dynamite

25% to 80% Strength

LOW FREEZING

Packed in white paper cartridge shells

Gelatin Dynamite is very dense and plastic. Having less bulk than other explosives of the dynamite class, it will give the same results as a larger quantity of a more bulky explosive. It may remain in water for several hours without losing its strength. It is suitable for tunnel operations, shaft sinking, submarine excavation, and blasting in mines and quarries where absence of fumes and water-resisting qualities are important. Practically no obnoxious fumes are produced by Gelatin Dynamite of less than 80% strength, an important feature in most underground work. Being plastic it can be loaded readily in upward, pitching or irregularly shaped bore holes.

Extra Gelatin Dynamite

40% to 90% Strength

LOW FREEZING

Packed in white paper cartridge shells

This explosive has the same general features as Gelatin Dynamite. As in the case of Atlas Extra Dynamite, ammonium nitrate takes the place of a part of the nitroglycerin used in Gelatin Dynamite.

Blasting Gelatin

100% Strength

LOW FREEZING

This is the most powerful (commercial) blasting explosive. It is slightly stronger than Nitroglycerin and might be graded as somewhat more than 100%. In substance it is like a very tough jelly.

Its water resisting qualities are excellent. It will retain its strength while under water for many hours. Owing to the tough elastic nature of the explosive, cartridges of considerably smaller diameter than the diameter of the bore hole should be used, so that they will not jam. The bottom of the tamping stick should be of greater diameter than the cartridge, so as to avoid the possibility of the stick pushing through the end of the cartridge.

As a rule not more than one-fourth to one-half of the full charge is made with this explosive, the remainder of the charge being composed of a weaker explosive. Blasting Gelatin should be used in small quantities until the user becomes familiar with its great power.

Blasting Gelatin is used in the backs or bottoms of "cut" holes in tunnels; in bottoms of quarry holes where the rock is very hard and in submarine blasting.

Oil Well Explosive

100% Strength

LOW FREEZING

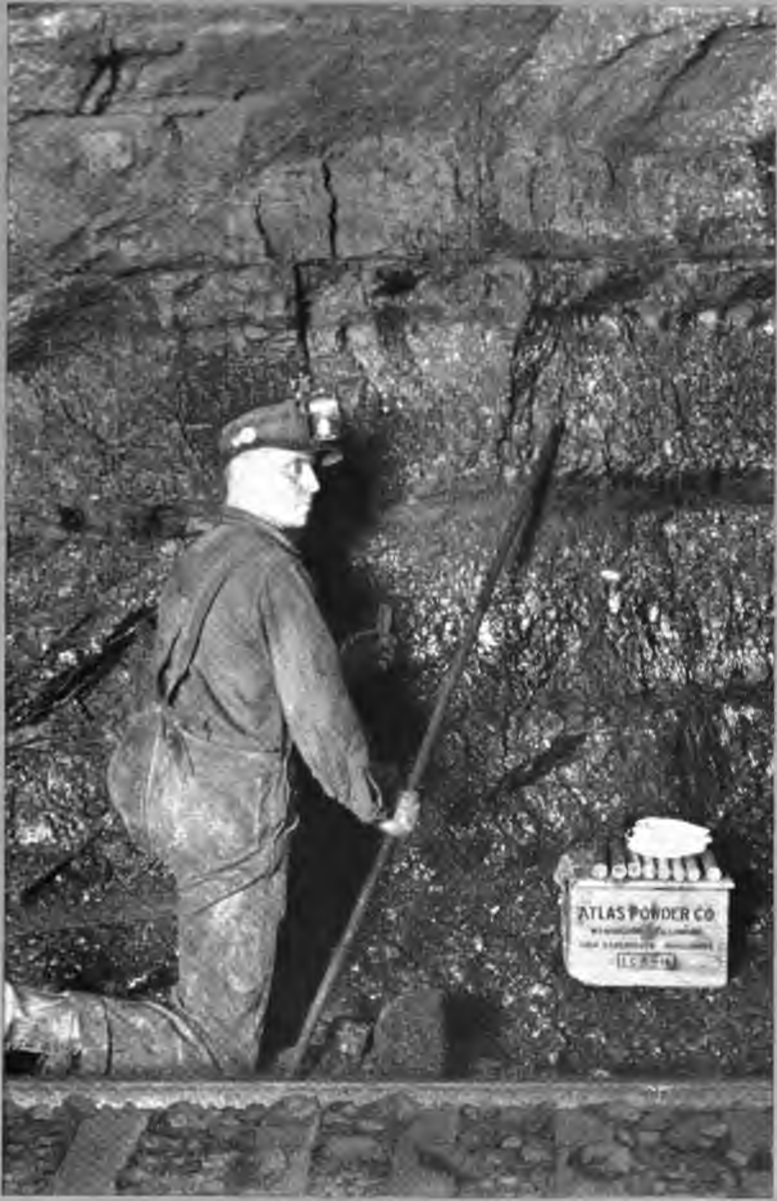
As liquid nitroglycerin is extremely hazardous to use, we perfected the explosive known as Oil Well Explosive. This explosive is safer than liquid nitroglycerin, and is accepted by railroads for transportation. It is used for the same purpose as nitroglycerin. Supplied in cartridges 2″ x 8″ and 4″ x 5.4″ packed in wooden cases, each case holding a quantity equal in strength to 10 quarts of liquid nitroglycerin. It is sold by the "quart," not by the pound, 2.85 pounds are equivalent in strength to a quart of liquid nitroglycerin. It is a 100% explosive. Nothing weaker than an Atlas No. 8 blasting cap should be used to detonate it.

Oil Well Explosive No. 2

80% Strength

LOW FREEZING

Oil Well Explosive No. 2, 80% strength, is similar to Oil Well Explosive 100% strength except in strength and manner of packing. This explosive is packed one 25 lb. block to the case or one 50 lb. block to the case. It also is packed in cases marked 10 quarts, weighing 33.7 lbs., and in cases marked 15 quarts, weighing 50.55 lbs.



Loading a bore hole in an Anthracite Coal Mine

Coalite

A Permissible Explosive

Made in 10 Grades

Packed in white paper cartridge shells

These explosives have been approved after official tests, by the United States Government Bureau of Mines. If used in accordance with the Bureau of Mines regulations, they will not ignite the explosive dust or gases found in coal mines.

Some coal can be broken best with a dense explosive. Other coal must have a bulky explosive. Some coal cannot be broken except with a very strong explosive, while with certain other kinds of coal a strong explosive merely shatters and blows out a "pot hole."

Some coal is broken most effectively with a slow acting explosive, while other coal can be mined much better when a quicker acting one is used.

All of these requirements are met by the various grades of Coalite. There are grades that are quick, that are slow, that are strong, that are weak, that are dense and that are bulky.

TABLE SHOWING RELATIVE PROPERTY VALUES OF VARIOUS GRADES OF COALITE

Coalite A L. F.	—very strong	—quick acting	—bulky
Coalite B L. F.	—strong	—quick acting	—very bulky
Coalite C L. F.	—strong	—quick acting	—moderately bulky
Coalite D L. F.	—strong	—quick acting	—very bulky
Coalite E L. F.	—strong	—slow acting	—moderately bulky
Coalite F L. F.	—relatively weak	—very slow acting	—moderately bulky
Coalite G L. F.	—strong	—slow acting	—very bulky
Coalite H L. F.	—moderately strong	—slow acting	—dense
Coalite No. 4 L. F.	—relatively weak	—slow acting	—very bulky
Coalite LN	—moderately strong	—quick acting	—dense

Coalites E, F and H, are ideal explosives for soft bituminous coal mines, where the coal is easily broken and where blasting powder of coarse granulations has been used.

Coalites A, C, D, and G are particularly adapted to anthracite and the harder bituminous coal.

Coalite B ranks between these two groups.

Coalite LN is a non-freezing, relatively strong, dense and quick acting permissible explosive.

In addition to their properties of strength, velocity and density, all Coalites will resist considerable dampness and moisture without any appreciable damage. Even those that may freeze are unaffected by low temperatures (except, of course, exposure to severe cold) and they do not give off any harmful or objectionable fumes. All of these explosives, except Coalite LN, however, will do better work when warm than when chilled.

Representatives who are thoroughly experienced in the use of explosives in all classes of coal mining will, upon the request to our Service Division, gladly consult with you about your mining problems.

Atlas Permissibles play an important part in the production of all kinds and grades of coal

Low Powders

5% to 20% Strength

LOW FREEZING

There are four grades.

R. R. P.—slow acting—5% strength.

F—a little faster—10% strength.

FF—still faster—15% strength.

FFF—fastest and strongest of the series—20% strength.

These four grades are called Low Powders, although strictly speaking they are explosives of the dynamite class because they must be detonated.

The "F" powders are suitable for blasting where a strong or quick explosive would be too violent.

R. R. P. may be classed in point of strength between explosives of the dynamite class and blasting powder. It is adapted to conditions where blasting powder would

not be strong enough nor quick enough to do the work; and where the material is not too tough. It will work well in railroad cuts; in stripping the overburden from mining material and in quarries.

For the three higher grades a No. 6 blasting cap or a No. 6 electric blasting cap should be used for detonation. When detonating R. R. P. the cap should not be placed in the charge itself. A primer of dynamite, 40% or stronger, should be used.

R. R. P. is granular in form and packed in 12½ pound paraffined paper bags, 4 bags, 50 pounds, to the case.

The "F" grades are packed in cartridges of standard size and shipped in 50 pound cases.

A 12½ pound bag of R. R. P. is considered equal in actual strength to a 25-pound keg of blasting powder.

Quarry Powders

LOW FREEZING

Though known as Quarry Powders, these explosives are of the high explosive or dynamite class, and must be detonated with a blasting cap.

These have been produced to meet special conditions that may exist in quarry work. There are three explosives in this group as follows:

Quarry Special No. 2 L. F.—Very bulky, strong, slow acting.

Quarry Powder L. F.—Not as strong as Quarry Special No. 2 L. F., but it is much more dense and is considerably quicker acting.

Quarry Extra L. F.—Has same density as, but is slightly weaker than, Quarry Powder L. F., about as quick acting as Quarry Special No. 2 L. F.

These dynamites rank relatively high in their ability to resist moisture.

Atlas Ammite

Made in 6 Grades

NON-FREEZING

This explosive does not—cannot freeze. The coldest temperatures do not affect it. This eliminates the necessity of thawing. Furthermore, this explosive possesses other qualities that are equally important:

Atlas Ammite is not highly inflammable like some dynamites. It may be kept for an indefinite time if stored in a proper storage magazine. Age has no harmful effect on it. Atlas Ammite is made in 6 grades as follows:

75%, 60%, 50%, 40%, 35% and 30%.

Atlas Ammite is quick acting, somewhat bulkier than Nitroglycerin Dynamite and Extra Dynamite and equal in water resistance to Extra Dynamite.

There are sufficient strengths to meet practically all blasting requirements. It is equally effective in mine or quarry, clay pit or stripping —above or below ground.

Men with expert knowledge of explosives and their uses will, on a request to our Service Division, help you determine what grade of Atlas Ammite is exactly suited to your blasting.

Atlas Farm Powder

LOW FREEZING

The Safest Explosive
The Original Farm Powder

This powder was developed by the Atlas Powder Company especially for use on the farm. It is an approved form of dynamite, with just the right properties to do the work the farmer requires of an explosive.

It is most effective for the removal of stumps and boulders, for breaking up the subsoil, preparing beds for trees, blasting ditches and post holes and for many other kinds of work on the farm. Atlas Farm Powder will do this work better than ordinary dynamite, and more economically. It is not easily affected by cold, seldom if ever requires thawing and it is safe to handle, store and use.

A 184 page, illustrated book, "Better Farming with Atlas Farm Powder," has been issued. It describes in detail the many ways in which Atlas Farm Powder may be used. A copy of this book will be sent upon request.

Atlas Farm Powder is used with excellent success in road work, clay pits, and other forms of earth excavation.

Atlas Non-freezing Farm Powder

NON-FREEZING

This Farm Powder does not—cannot freeze. Aside from making thawing unnecessary, this explosive has these advantages: Not highly inflammable like some dynamites. May be kept for an indefinite time if stored in a proper storage magazine.

Atlas Non-freezing Farm Powder is moderately quick acting, somewhat bulkier than Nitroglycerin Dynamite and Extra Dynamite and equal in water resistance to Extra Dynamite.

Atlas Stumping Special No. 2 L. F.

LOW FREEZING

An explosive made to meet special conditions in stump shooting. It is very bulky, strong and slow acting—an ideal explosive for giving the slow, heaving, powerful action required in removing firmly rooted stumps.

Atlas Blasting Powder

There are two kinds:

"A" Blasting	"B" Blasting
(6 granulations.)	(8 granulations.)

All granulations have the same strength, the difference in size determining the difference in action. The finer the grain the speedier the action. The finer granulations, therefore, shatter more than the coarser ones.

Blasting powder is granular in form. Color black.

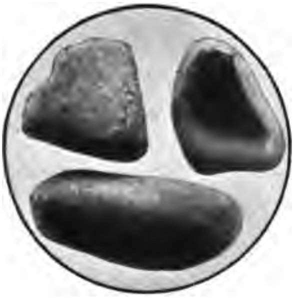
"B" grade is made of charcoal, sulphur and sodium nitrate.

"A" grade is composed of charcoal, sulphur and potassium nitrate. "A" Blasting Powder is somewhat more dense and shows a slightly better resistance to moisture. The grains of both "A" and "B" blasting powder are glazed over with graphite.

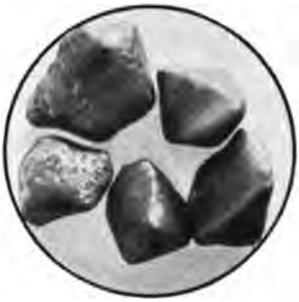
The smooth surface thus obtained causes the powder to flow freely and pack tightly in the bore holes.

Because of its lower cost "B" Blasting Powder is used more extensively than "A" Blasting Powder.

The coarsest granulation of "B" Blasting Powder is CCC and the finest is FFFF. The coarsest granulation of "A" Blasting Powder is C and the finest is A Dust.



CCC



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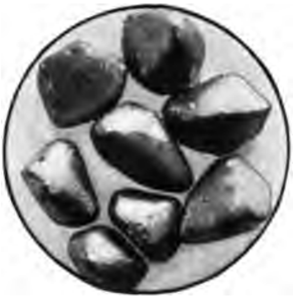

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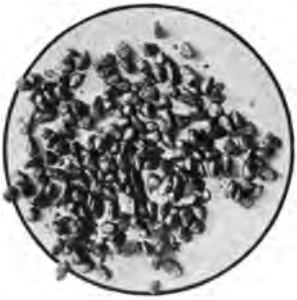
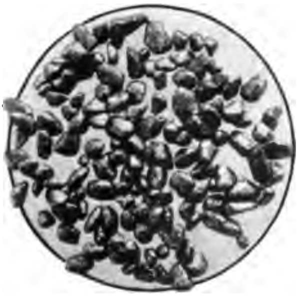
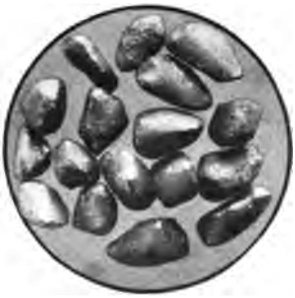


FFFF



FFF



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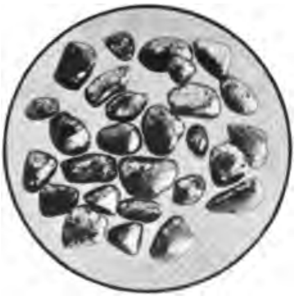


FF

Standard granulations of "B" Blasting compare in size with the standard granulation of "A" Blasting Powder as follows:

"B" BLASTING POWDER	"A" BLASTING POWDER
Stand. 1—CCC	
Stand. 2—CC	
Stand. 3—C	
Stand. 4—F	Stand. 1—C
Stand. 5—FF	
	Stand. 3—FF
Stand. 6—FFF	
Stand. 7—FFFF	
	Stand. 7—FFFF
	Stand. 8—5F
	Stand. 10—7F
Stand. 57 R. R. consists of Stand. 5, 6 and 7	Stand. 11—A Dust

Packed in sheet steel kegs, 25 pounds in a keg.

Squib Powder

Squib powder is furnished in two grades: FFFG and SPECIAL.

Sporting Powders and Fireworks Powders

The Atlas Powder Company furnishes Black and Smokeless Sporting Powders, also Fireworks Powders.

ATLAS BLASTING SUPPLIES

Safety Fuse

SAFETY Fuse is used for exploding blasting powder and for detonating blasting caps. It consists of a core of fine-grained powder wrapped in several different kinds of material varying with the brand of fuse. The several different kinds of fuse may be grouped into three general classes—

1—For dry work.
2—For damp work.
3—For wet and under water work.

The list of brands is as follows:—

BRAND	USE
Cotton	Dry work only.
Single Tape	Damp work.
Double Tape	Wet work.
Triple Tape	Very wet work where exposed to rough treatment under water.
Beaver	Damp work. Suitable for most agricultural blasting. Double countered.
Charter Oak	Wet work. A very good general purpose fuse. Triple countered.
Clover	Wet work or under water. Waterproof coating protected by a paper tape. Double countered.
Anchor and Crescent	Very wet work or under water. Standard mining fuse. Taped and double countered.
Reliable	Wet work. A pliable fuse. The gutta-percha covering is not protected with a tape. Double countered.

NOTE: Cotton fuse is too small in diameter to properly fit the standard blasting cap, and should be used only to fire blasting powder charges.

Each roll of fuse contains two 50-foot sections, one within the other. Fuse is packed for shipment in wooden cases of various sizes, containing the following lengths:

500 feet 1000 feet 2000 feet 3000 feet
4000 feet 5000 feet 6000 feet

The average burning speed of fuse when fired in the open is 90 seconds per yard, 30 seconds per foot (except Charter Oak and Clover brands which have an average burning speed of 40 seconds per foot). Any fuse may burn 10% faster or 10% slower. This is a usual variation.

The burning speed of some fuse if under pressure of an exceptionally solid tamping may increase more or less according to conditions.

When safety fuse is used to fire a round of shots in sequence or rotation, the arrangement to fire the different sets of holes at different intervals of time is a very simple one. The fuse for the first round is cut the shortest, but long enough to give time for the shot-firer to light the other rounds and then reach a place of safety. The fuse for the next round to be fired is cut several inches longer and for the remaining rounds a length that will fire at the proper interval of time.

Detonators

There are two distinct kinds of detonators: Blasting caps, exploded by burning fuse, and electric blasting caps, exploded by an electric current. They are similar in that each is a cylindrical copper tube containing a powerful explosive (usually fulminate of mercury). The blasting cap has one end open, into which the blaster inserts fuse to fire. The electric blasting cap has both ends closed, but sealed into one end are two wires, the ends of which are connected by a "bridge" and embedded in the explosive charge. The current of electricity heats this bridge and fires the detonator.

Blasting caps and electric blasting caps are made in two strengths, No. 6 and No. 8. The amount of explosive charge in electric blasting caps is the same as in the corresponding grade of blasting caps.

As blasting caps and electric blasting caps differ in other respects, they are listed separately.

Carton containing 5 boxes of 100 Atlas Blasting Caps to each box.

Blasting Caps

DIMENSIONS OF BLASTING CAPS

		No. 6	No. 8
Length of shell		1½"	2"
Outside diameter of shell		.235	.235
Weight of explosive charge	Grams	1.	2.

No. 6 and No. 8 blasting caps are supplied in tin boxes as follows: 10 in oval box, 25 in an oblong box, 100 in a round or oblong box.

For shipping, boxes are packed in cartons and enclosed in heavy wooden cases.

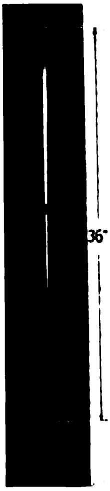
CAPACITY OF SHIPPING CASES

Kind and Grade	Case No.	Quantity	Net Wt.	Gross Wt.
Atlas No. 6........	0	500	2¾ lbs.	5¾ lbs.
	1	1000	5¾ "	11 "
	2	2000	11½ "	19 "
	5	5000	28¾ "	37 "
Atlas No. 8........	0	500	4 "	8 lbs.
	1	1000	8½ "	14 "
	2	2000	17 "	24 "
	5	5000	42½ "	58 "

Electric Blasting Caps

There are two kinds of electric blasting caps:

1. Electric Blasting Caps (Instantaneous).
2. Delay Electric Blasting Caps.



Photograph of the length of the flash produced by the match head of an Atlas Electric Blasting Cap

Electric blasting caps are supplied with tin covered, copper or iron wires, having black or white insulation, in lengths in multiples of 2, from 4 feet up to 20 feet. Longer lengths are made to order. Iron wires are supplied to reduce the cost to the user; it requires five to six times the voltage to fire iron wire electric blasting caps as those with copper wire of the same length.

Not only the cap itself but the wires must be handled carefully. The wires must not be sharply bent or twisted at the point of entering the cap. Before joining the ends of wires to other wires they should be scraped to insure perfect contact. While the wires have a water resisting covering, in deep water or in any wet material where they are under pressure, the electric current may leak. To overcome this possibility, a surplus of current should be used.

Atlas Electric Blasting Caps and Carton

DIMENSIONS OF ELECTRIC BLASTING CAPS

Length of shell	No. 6	$1\frac{9}{16}''$	No. 8	2″
Outside diameter of shell	"	.273″	"	.273″

Electric blasting caps are supplied in pasteboard cartons, each containing 20 to 50, according to the length of the wires.

CAPACITY OF CARTONS

2 to 12 ft. wires—50 to carton
14 to 26 ft. wires—25 to carton
28 to 40 ft. wires—20 to carton

Cartons are shipped in heavy wooden cases.

Atlas Waterproof Electric Blasting Caps and Carton

Waterproof Electric Blasting Caps

For submarine and any other very wet work, the caps and wire are made with special waterproofing.

Delay Electric Blasting Caps

Delay electric blasting caps are constructed so that they will fire as many as six sets of shots in a "round." This is all that is required in many different blasting operations. The instantaneous cap should be placed in the center-cut holes; the First Delay in the relief or rib-holes; the Second Delay in the top or "lifter" holes; and so on. All are fired by one application of the electric current.

The various delays of Atlas Delay Electric Blasting Caps are distinguished as follows: First Delay, white wires and tagged **1st**; Second Delay, blue wires and tagged **2nd**; Third Delay, red wires and tagged **3rd**; Fourth Delay, green wires and tagged **4th**; Fifth Delay, yellow wires and tagged **5th.**

Atlas Delay Electric Blasting Caps (five different delays) and Carton

Delay electric blasting caps are supplied in pasteboard cartons, containing 15 to 50 according to the length of the wires. Cartons are packed in heavy wooden cases.

On the diagram shown on page 19 suggestions are given for arranging shots in tunnel or shaft blasting. Special suggestions for arranging the holes for either of these purposes will be supplied by our Service Division. (See chapter VII on "Service," pages 109 and 110.)

The advantages of using delay electric blasting caps may be summed up briefly as follows:

1. The material to be blasted can be brought down in sections with but one application of the electric current and without having to return to the face several times to make connections.

2. The blasting of each section makes way for the next section to be broken out.

3. The danger of damage to nearby structures, such as timbered work, is materially lessened when the round is fired in successive intervals instead of being fired all at once.

Atlas Delay Electric Igniters (five different delays) and Carton in which they are packed

Delay Electric Igniters

These are cylindrical copper tubes, in one end of which electric wires are placed. In the other end is a short piece of fuse. For the detonation of a high explosive, a blasting cap must be crimped to the end of the fuse. (If used in blasting powder, the blasting cap is not needed.)

As many as six shots may be fired with one application of the electric current. The length of the fuse varies according to the intervals desired:

No. of Delay	Length of Fuse
1st Delay	2½ Inches
2nd Delay	4½ "
3rd Delay	6½ "
4th Delay	8½ "
5th Delay	10½ "

When priming, an electric squib is used in the charge that is to explode first, if the explosive is blasting powder. When the explosive is dynamite and blasting caps are crimped to the igniters, the first shot of the series is primed with a regular instantaneous electric blasting cap.

Caution:—Use only one make of electric blasting caps or igniters in any one round of shots.

Miners' Squibs

The several varieties of miners' squibs are alike in general form. Each one is a small paper tube, made tapering in shape. It contains a charge of fine-grained black powder. One end of the paper wrapping is treated with chemicals so that it will ignite easily but will burn slowly. This forms what is known as a "slow match." The slow burning of this match allows sufficient time for the miner to reach a place of safety.

BLUE LABEL AND RED CROSS SQUIBS

Sulphur Squibs, Gas Squibs

Packed 100 to the box, 100 boxes—10,000 squibs—to the case.

The special features of these squibs are: The length of the slow match, which provides sufficient time for the operator to get outside the zone of danger; the slow match is arranged so that it may be ignited without unrolling thereby saving time and labor; and the squib is formed so that it is impossible for any of the explosive to get into the slow match.

D. and B. SQUIBS

Packed 100 to the box, 100 boxes to the case, 50 boxes to the half case.

No. 1—This can be used in mines where gas is not present in dangerous quantities. The slow match makes a small flame when it burns. The boxes bear *yellow* labels.

No. 2—Similar to No. 1 described above, but is made especially for the deep pitching veins of the anthracite coal fields.

No. 3—The slow match does not burn with a flame. It makes only an ember in burning and will not ignite gas. For convenience in igniting the slow match touch paper is provided.

POWELL SQUIBS

Packed 100 to the box, 100 boxes to the case.

Rocket No. 1—This can be used in mines where gas is not present in dangerous quantities. The slow match makes a small flame when it burns. The boxes in which these squibs are packed have *yellow* labels.

Gas No. 2—For use in a gassy mine. This slow match does not burn with a flame. It makes only an ember in burning, and will not ignite gas. For convenience in igniting the slow match prepared paper is provided. It is called "touch paper." The boxes have *red* labels.

Superior Safety Gas Squibs—This is practically the same as the Powell Gas Squib No. 2 with an important improvement. At the point where the slow match connects with the squib itself there is a special device which makes it impossible for any of the explosive to be in the slow match itself. These boxes also have *red* labels.

Atlas Electric Squibs and Carton

Electric Squibs

Packed 50 to the carton, 10 cartons to the case.

The electric squib is equipped with either copper or iron wire and is for use with blasting powder only.

The wire lengths supplied are:

Copper: 4, 6, 8, 10 and 12 feet.
Iron: 4, 6 and 8 feet.

The iron wire electric squibs cost less than the copper wire but a higher voltage is required to fire them.

The electric squib is similar in appearance to the electric blasting cap, except that its shell is made of paper instead of copper. One end of the paper shell is closed by a small cork to protect the contents. The electric squib, when fired, shoots out a small flame. It is delicately made and requires careful handling.

All Atlas Electric Blasting Caps are subjected to two electrical tests. Illustration shows operator making the second test.

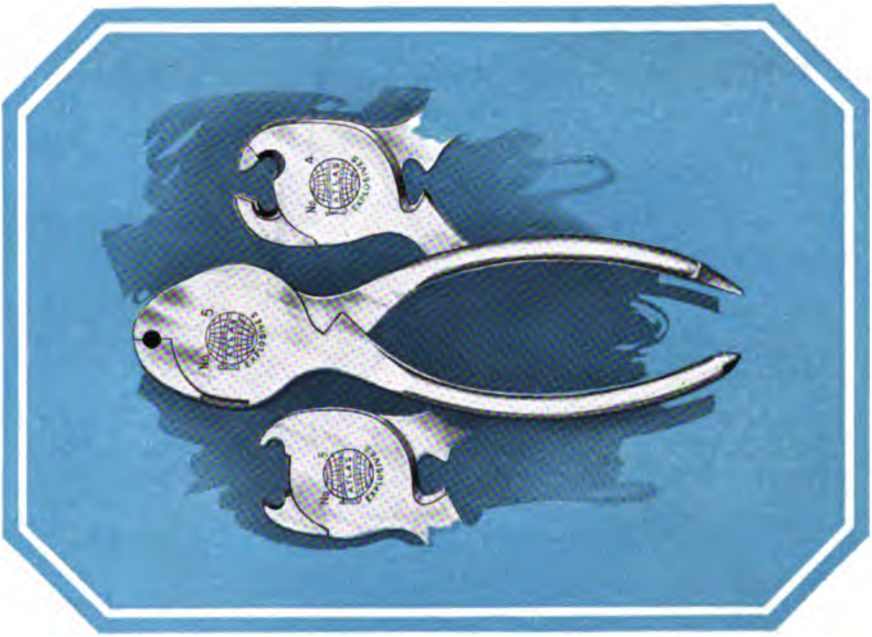
The use of the electric squib offers several advantages: The firing is done by electric current, enabling all operators to be outside the danger zone when the charge is fired; it can be placed at or near the centre of the charge, which will produce far better results than when the end of the charge is ignited, as when fuse is used; it can be operated more quickly than fuse; several shots may be fired simultaneously with little danger of misfires or hang fires and without the smoke created by the burning of fuse.

Cordeau-Bickford

This is an instantaneous detonating fuse in the form of a thin lead tube filled with TNT. It is used as a detonating agent for explosives and is particularly adapted to detonating long columns of explosives such as are encountered in well-drill blasting. When it extends the entire length of the charge it increases the velocity of slower explosives to its own velocity. The rate of detonation of Cordeau is very rapid (approximately 17,000 ft. per second).

It weighs about ten pounds per hundred feet, is wound on wooden spools in lengths of from 100 feet to 500 feet and is supplied in three different forms, No. 6 plain, No. 6 countered, and No. 6 double countered. The object of the countering is to protect the Cordeau when tamping and to strengthen it when used in long lengths.

The following accessories which are necessary in the use of Cordeau-Bickford are supplied: Cordeau Slitters (for splitting the ends of branch lines), Cordeau Crimpers, Straight Unions, Special Unions, and Couplings.



Cap Crimpers

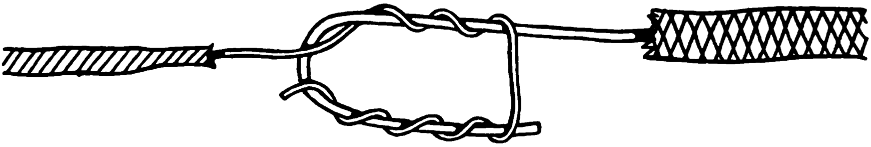
The cap crimper offers the only sure means of crimping the blasting cap on the fuse in such a way that it stays in its proper place and is protected from dampness. Other methods of fastening caps to fuse are dangerous and often cause misfires.

One of the handles of the cap crimper is pointed so that it may be used for punching the hole in the cartridge for priming.

Leading Wire and Connecting Wire

The wire used to connect the blasting machine with the electric blasting caps, igniters, squibs, etc., is called "Leading Wire." The wire used to connect the shots together in a single circuit when the wires of the caps themselves are not long enough, is called "Connecting Wire."

Leading wire is insulated copper wire (No. 14 Brown & Sharpe gauge). It is supplied in either single or duplex form. The duplex form consists of two single wires bound together and having an additional insulated covering.



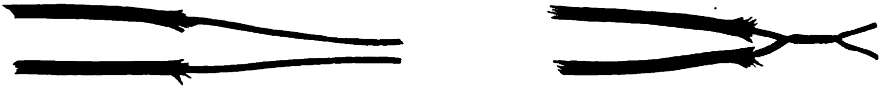
A good way to insure proper contact when attaching connecting wire or electric blasting cap wire to leading wire

The lengths in which single and duplex wires are supplied, and the weights of the single wire are:

200 ft. coils	Weight about 4.12 lbs.
250 ft. coils	Weight about 5.15 lbs.
300 ft. coils	Weight about 5.97 lbs.
500 ft. coils	Weight about 9.89 lbs.

The weight of duplex wire is approximately twice that of single wire.

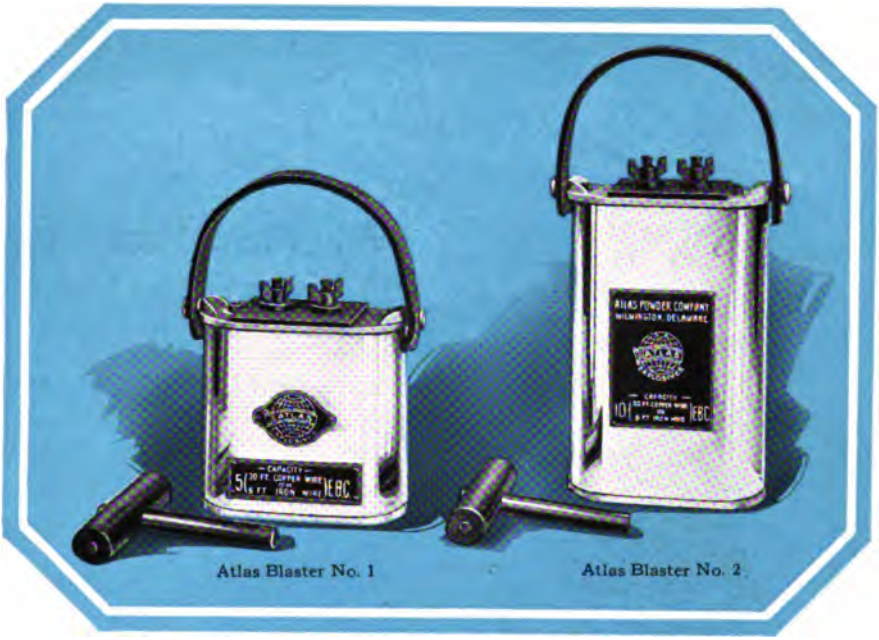
Connecting wire is small insulated copper wire (No. 20 or 21 Brown & Sharpe gauge) and is supplied on 1 lb. and 2 lb. spools. A one pound spool contains about 230 feet of No. 20 wire or about 290 feet of 21 wire.



Method of connecting electric blasting cap wires to each other or to connecting wire

Blasting Machines

On the following pages will be described separately the several blasting machines. These are used for supplying current for electric blasting. The method of using them is explained in Chapter V, page 103.



Atlas Blaster No. 1 Atlas Blaster No. 2

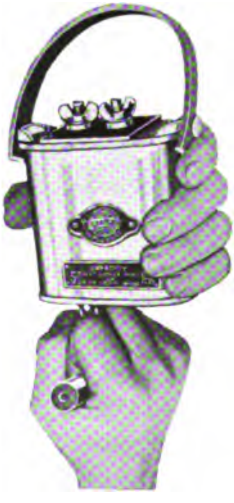
The Atlas Blaster

The Atlas Blaster is an especially handy machine—a general purpose machine that is light in weight and provided with a leather strap for carrying.

This machine is operated by a key which is a separate part of the machine. This key may be kept in possession of the shot firer, thus preventing the operation of the machine by any other person.

The operation of this blaster is simple: Machine is held in left hand (bottom toward operator). The operating key, grasped in right hand, is inserted in the socket with back of hand toward operator. A quick twist of the handle to the right fires the blast. The more quickly the twist is made the greater the power developed.

Based on insulated wire of lengths not exceeding 600 ft. for No. 14 wire, 350 ft. for No. 16 wire, or 200 ft. for No. 18 wire, Atlas Blasters will fire the rated number of blasting caps stated in the specifications given for the respective sizes.



Method of operating Atlas Blasters Nos. 0, 1 and 2

Atlas Blaster No. 0

Atlas Blaster No. 0*

This blasting machine bears the permissible plate of the U. S. Bureau of Mines and should be used for the sake of safety in gassy and dusty coal mines.

Capacity: Will fire one 30-foot copper wire electric blasting cap or one 6-foot iron wire electric blasting cap.

Dimensions: 4¾″ x 2″ x 4½″ high.
Net Weight: 3¼ lbs.
Shipping Weight: 4 lbs.

Atlas Blaster No. 1*

Capacity: Will fire five 30-foot copper wire electric blasting caps or five 6-foot iron wire electric blasting caps connected in single series.

Dimensions: 4¾″ x 2″ x 4¾″ high.
Net Weight: 3¼ lbs.
Shipping Weight: 4 lbs.

Atlas Blaster No. 2*

Capacity: Will fire ten 30-foot copper wire electric blasting caps or ten 6-foot iron wire electric blasting caps connected in single series.

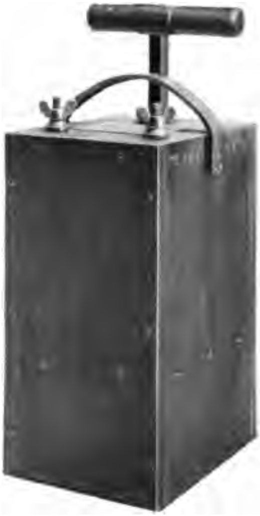
Dimensions: 4¾″ x 2″ x 6¾″ high.
Net Weight: 5½ lbs.
Shipping Weight: 6½ lbs.

*(The Atlas Blaster should not be short-circuited at the binding posts, as this will weaken the permanent magnet and reduce the capacity of the machine. This applies whether the machine is in operation or not and the user is cautioned against permitting metal plates to bear on both binding posts at the same time or attaching two ends of the same wire to the posts.)

Atlas No. 3 Blasting Machine

The improved Atlas No. 3 Blasting Machine is the result of considerable experimental work. By the use of the proper materials and improved design, it has been possible to build a blasting machine of high capacity, great durability and smooth operation. The capacity of this machine is far in excess of the old type blasting machines of equal weight. Resistance to the thrust of the rack bar does not appreciably increase during operation, resulting in a machine with a very smooth action.

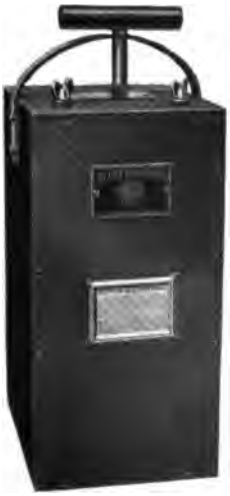
Standard size for quarry, mine and ditch blasting. It is strong and substantial, and one of the most useful sizes of blasting machines.



No. 3

Capacity: Will fire fifty 30-foot copper wire electric blasting caps or fifty 6-foot iron wire electric blasting caps connected in single series.

Dimensions: 7″ x 8″ x 14¾″ high.
Net Weight: 22 lbs.
Shipping Weight: 31 lbs.



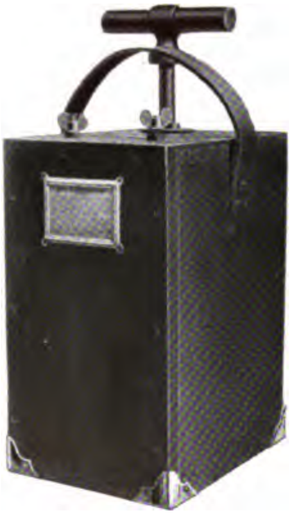
No. 5

U. S. Standard No. 5 Blasting Machine

This machine is the same general style as the Atlas No. 3, but differs considerably in design.

Capacity: Will fire one hundred 30-foot copper wire electric blasting caps or one hundred 6-foot iron wire electric blasting caps connected in single series.

Dimensions: 9″ x 11″ x 21″ high.
Net Weight: 57 lbs.
Shipping Weight: 75 lbs.



No. 6

U. S. Standard No. 6 Blasting Machine

Also a hand-operated, push-down machine.

Capacity: Will fire one hundred and fifty 30-foot copper wire electric blasting caps or one hundred and fifty 6-foot iron wire electric blasting caps connected in single series.

Dimensions: 8½" x 10¾" x 17½" high.
Net Weight: 41 lbs.
Shipping Weight: 55 lbs.

Mason Turbine Blasting Machine

This is a machine operated by steam or compressed air. It includes an electric generator and a turbine motor, connected by a direct shaft. The turbine requires 80 lbs. pressure to drive it at full speed and cannot be used properly with less.

The machine is enclosed in a well-finished, brass-bound, hardwood case with hinged cover. The push-button, switch, voltmeter and binding posts are on top. This arrangement adds greatly to convenience in using. The exhaust steam or air escapes through an iron extension pipe on the end of the case.

To prepare for operating the machine, the leading wires should be connected to the binding posts and the power turned on. The turbine drives the generator. The generator builds up the current. When the push button is depressed, the voltmeter will indicate the "firing point." When all is ready for firing, the switch is turned.

Mason Turbine Blasting Machine

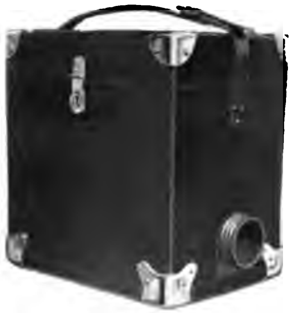


Fig. 1.—Showing turbine closed for carrying

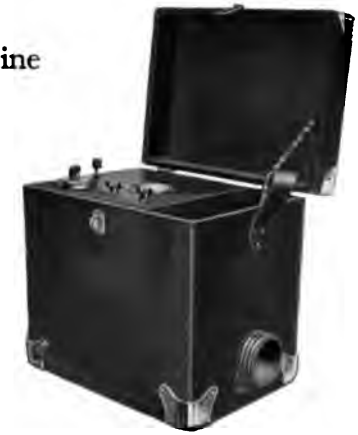


Fig. 2.—Showing turbine open for use

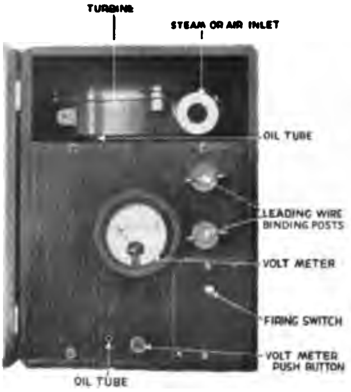


Fig. 3.—Showing turbine looking straight down upon it

Capacity: One hundred and fifty 30-foot copper wire electric blasting caps, or one hundred and fifty 6-foot iron wire electric blasting caps connected in single series.

Dimensions: 8⅞" x 13" x 12" high.
Net Weight: 44 lbs.
Shipping Weight: 55 lbs.

Repairs for Blasting Machines

The blasters and blasting machines that we recommend are carefully constructed and made of the best material obtainable. They are fully guaranteed to be free from defect in material and workmanship and, with proper care, any model described in this catalog should give years of service in the particular work for which it is recommended.

Should any Atlas machine fail to give such service it should be returned to us, charges prepaid. If after examination, it is found that the trouble is due to defective workmanship or material, the parts will be replaced free of charge and the machine returned transportation prepaid and customer will receive credit for transportation prepaid.

On the other hand, if it is found that the trouble is due to ordinary wear, abuse or lack of care, the repairs needed will be made and the machine returned transportation charges collect. The parts required to put machine in proper working order will be billed to owner.

We *do not* ship repair parts to owners of blasting machines as we have found that machines repaired in our own shops give better service than those repaired in the field.

Reminders for the Electric Blasting Machine Operator

Make all connections in series when using blasting machines. If light or power lines are available connections may be made in parallel or parallel series.

Keep the blasting machine in good order. Test it occasionally with an Atlas Rheostat.

*"Do not clean the commutator with emery cloth; use No. 00 sandpaper. Keep slots in commutator free from metallic particles, use a piece of wood to clean the slots—never a knife or sharp metal.

"Do not clean contact points in such a manner as to remove platinum points. These points protect the brass from oxidation under the influence of the hot electric spark and are essential to the proper generation of the current.

---

*Quoted from *The Detonator*.

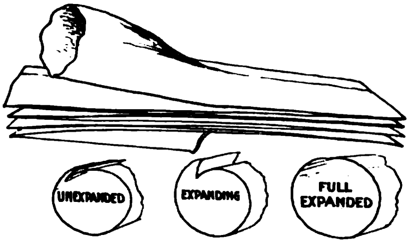
"Do not connect leading wires to the blasting machine until ready to fire, and if for any reason upon operating the blasting machine, the round should fail to fire, disconnect both wires immediately.

"Test the complete round through the leading wires with an electric blasting type galvanometer before connecting the circuit to the blasting machine."

The bearings of the armature shaft and of the armature itself should be oiled occasionally, but care should be taken not to allow the oil to touch the brushes, commutator, contact spring or its contact points.

Wipe off with an oiled cloth the steel parts that can be reached, the faces of the armature (not the wire) also the rack bar and the guide rod. A thick cylinder oil rubbed into the grain of the wood of the machine will help to preserve the case. Should the brushes appear to be wearing into the commutator too rapidly, a little graphite may be taken from a soft lead pencil and used for lubricating the commutator. If by accident any oil should lodge on the commutator, it should be removed at once. A cloth dampened with gasoline will serve for this purpose. All of the gasoline and its vapor should be removed from the box before it is closed.

It pays to use care in making wire connections for electrical firing



Sureshot Blasting Shells

For Black Powder—For Tamping Material

The Sureshot Blasting Shell is a continuous, expansible paper tube made of the stoutest waterproof paper. Its patented construction gives it many advantages over the method of loading black powder with blasting paper. The shell is loaded in the usual way. When the charge is pressed in the bore-hole the tamping expands the shell without breaking the paper, the charge fills the hole completely, yet the powder is protected from water or moisture in the hole. The best results are, therefore, obtained from the explosive and "lost holes" or misfires are reduced to a minimum.

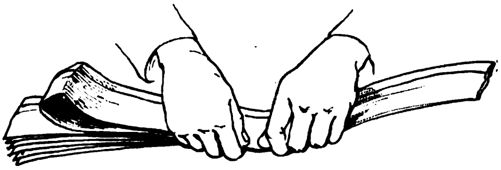


Fig. 1

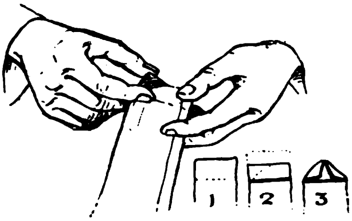


Fig. 2

How to Use Sureshot Shells

1. Tear off enough shell for the length of shot you wish to make.
2. Crimp the End—One flat fold, then turn over the corners. (Twist it if you want to.)
3. Open the Shell—Blow in it. (Using your thumb will take twice as long.)

4. Slide your hand to the bottom pressing the creased edges together. It will stand open.
5. Fill with powder.
6. Work down the powder with stripping motion. It will pack tight.

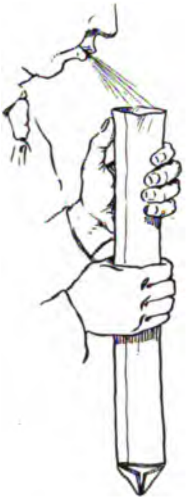


Fig. 3

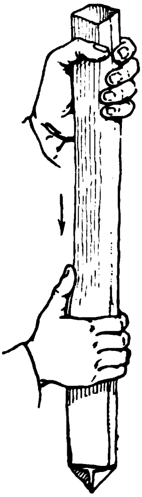


Fig. 4

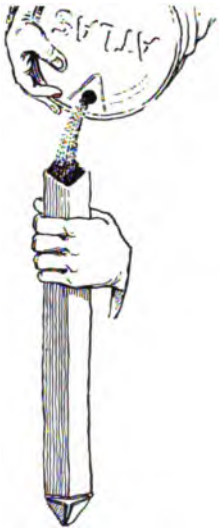


Fig. 5

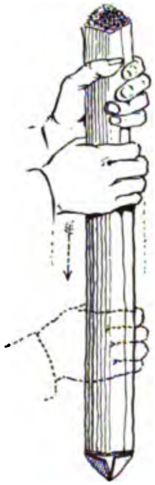


Fig. 6

Sizes of Sureshot Shells

These Shells are made in the following standard sizes:

1¼″	Unexpanded Diameter.	Weight per package	45 lbs.
1½″	Unexpanded Diameter.	" " "	45 "
2″	Unexpanded Diameter.	" " "	75 "

Each shell is 40 feet in length, folded in 10-inch folds. This is the standard length of blasting paper for some coal fields. Packed 100 shells in a package.

Any size desired can be furnished. Any length in any size can be supplied.

Tamping Bags

Before being filled

Tamping bags are made especially for holding tamping material for explosive charges in horizontal holes or in "uppers," where the ordinary method of tamping is not practical. They are inexpensive and are great time savers. They are sometimes used in coal mining operations to make powder cartridges.

They are packed in bundles of 500 each, ten bundles to the bale. Each bag is about 2 inches longer than the listed length. This is to provide a margin for folding over the end when it is used.

The following table shows sizes and shipping weights of Atlas Tamping Bags:

Tamping Bag filled

Size No.	Size	No. in Bale	Shipping Weight Per Bale
A	1″ x 8″	5,000	21 lbs.
B	1¼″ x 8″	5,000	24 "
C	1¼″ x 10″	5,000	29 "
D	1¼″ x 12″	5,000	30 "
E	1½″ x 8″	5,000	28 "
F	1½″ x 10″	5,000	33 "
G	1½″ x 12″	5,000	39 "
H	1½″ x 16″	5,000	45 "
J	2″ x 18″	5,000	68 "

Blasting Paper

This is used for making cartridges to contain blasting powder. It also, is sometimes used for making up "tamping bags." It is supplied in bundles of 5 rolls each, weighing 22 pounds.

Kapseal

This is a wax-like material used for waterproofing joints between fuse and blasting cap, and for sealing the opening made in a cartridge where the cap enters. Packed in one-pound tin cans enclosed in pasteboard cartons. A case contains 24 cans.

Atlas Rheostat

For Testing Blasting Machines and Galvanometers

The Atlas Rheostat is a device for ascertaining, by means of artificial resistance, the number of electric blasting caps that a blasting machine will fire when the charges are connected in series. It also is used as a standard by which the resistance readings of galvanometers may be checked.

Complete instructions for the use of the Atlas Rheostat will be found in Chapter V, pages 104 to 106.

Dimensions: ¾" x 1¾" x 5½".
Weight: 5½ ounces.

Atlas Galvanometer

This is an instrument for testing electric blasting caps, single series circuits, etc., to make certain there are no poor connections, leaks or short circuits that will cause misfires. The instrument consists of a chloride of silver dry cell battery and resistance coil enclosed within a case made of metal and hard rubber which, in turn, fits into a leather case equipped with leather shoulder strap.

Method of using Atlas Galvanometer

Two contact posts are located at the upper side of the metal case. Complete instructions for using the Atlas Galvanometer will be found in Chapter V, pages 104 to 106.

Dimensions, including leather case: 1¾" x 3½" x 4½".

Weight, including leather case: 1½ lbs.

Thawing Kettles

For use when explosives are frozen or chilled. These thawing kettles are supplied in two sizes.

	Capacity	Weight empty	Weight of water	Total weight filled	Outside Dimensions
Atlas No. 1..	30 lbs.	12½ lbs.	40 lbs.	82½ lbs.	14" x 14½"
Atlas No. 2..	60 "	17½ "	77½ "	155 "	17½" x 21"

No matter what the size of the job, there is an Atlas Explosive especially suited to the work

Storage of Explosives

Explosives should be stored only in safely located and suitably constructed buildings. The construction of these buildings, popularly known as magazines, may vary considerably, depending upon the type of explosive to be stored, climatic conditions, permanency of storage and kind of building materials available.

In selecting locations for magazines, safety is the first consideration. Other considerations are the avoidance of excessive dampness and high temperature. The safety standard used by this Company in locating magazines is the American Table of Distances, copy of which will be sent upon application to any of our branch offices.

The construction of magazines for all classes of explosives should be such as to resist fire, weather, moisture and theft, while magazines for dynamite or similar high explosives should, in addition, offer resistance to bullets. The standard designs of magazine construction used by this Company include the following types:

Permanent Storage

(Magazines suitable for any form of explosive or blasting supplies.)

A;—Medium soft brick, laid in cement mortar, containing from 15% to 25% lime, with roof bullet-proofed with sand.

B;—Wooden magazines sheathed outside and lined inside with not less than ⅞" T. & G. boards, the intervening space between inner and outer linings to be filled 6 inches above sill with weak cement mortar, and remainder of space to plate with sand well tamped. Outside of building fireproofed with not less than 26 gauge iron.

C;—Permanent magazines suitable for blasting or sporting powders or blasting supplies; i. e., caps, exploders, fuse, etc. (This magazine not suitable for dynamite or similar high explosives.) Balloon constructed, outside to be sheathed with ⅞" lumber and fireproofed with not less than No. 26 gauge sheet iron; studding to be sufficiently rigid to resist load piled in magazine and not less than 2" x 4". Inside of building to be lined with 1" x 6" lining strips secured to studding, and spaced about 6 inches apart.

Plans and specifications for any of the above types of magazines will be furnished upon application to any of our branch offices.

Temporary Storage

For temporary storage, there may be purchased from this Company portable iron magazines, capacity, dimensions, and weight of which are as follows:

	Size	Capacity	Dimensions	Weight
			Lg. Wd. Ht.	
Portable Iron Powder Magazine No. 31........	0	50 lbs.	20x14x12 inches	52 lbs.
	1	8 kegs	24x24x25 “	145 “
	2	12 “	31x21x25 “	165 “
	3	16 “	40x21x25 “	195 “
	4	24 “	48x28x26 “	340 “
	5	30 “	50x30x30 “	390 “
Portable Dynamite Magazine No. 63..............	1	20 cases	42x39x54 “	450 “
	2	30 “	60x39x54 “	575 “
	3	40 “	78x39x54 “	700 “
Storage Magazine..........	1	108 kegs	3x 6x 6 feet	800 “
	2	216 “	6x 6x 6 “	1200 “
	3	324 “	9x 6x 6 “	1500 “
	4	504 “	9x 8x 7 “	2000 “
	5	672 “	12x 8x 7 “	2400 “
	6	840 “	15x 8x 7 “	2800 “
	7	1056 “	12x11x 8 “	3200 “
	8	1320 “	15x11x 8 “	3700 “
	9	1584 “	18x11x 8 “	4200 “
	10	1848 “	21x11x 8 “	4700 “

The above magazines are suitable for storage of blasting and sporting powders, blasting caps and other blasting supplies. If used for dynamite or similar high explosives they should be reinforced with brick or wood so as to offer resistance to bullets.

The above types of portable magazines are not recommended for storage of dynamite or other high explosives in warm climates, or where high summer temperatures prevail.

The above standards for locating and constructing magazines are supplementary to and subject to modification by any existing State or local laws regulating storage, delivery and use of explosives. Persons wishing to build magazines should inform themselves regarding such laws in order to comply therewith.

CHAPTER V

How to use Blasting Supplies

CAP AND FUSE FIRING

IN cap and fuse firing it is imperative that the cartridges be properly primed or costly misfires or accidents may result. Give this job to a careful workman, and hold him responsible for doing it properly. Insist that it be done only in a safe place.

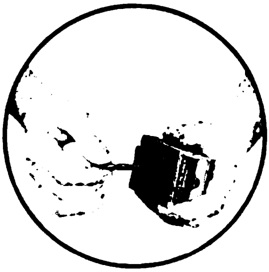
Handling the Fuse

In cold weather the fuse should be warmed slightly before uncoiling. This prevents cracking the outside covering in uncoiling. Place the fuse over a block of wood and with a sharp knife cut off the length desired. The end should be cut square. A ragged edge may cause a misfire. If the fuse has been cut for some time, make a fresh end by cutting off a small piece.

Cut off fuse square and clean

Removing Cap from Box

To take a blasting cap out of the box, place one hand over the top. Tilt the box slightly until one or more of the blasting caps start to slide out. Then pick one out. Do not try to take a blasting cap out of the box with a nail, stick or end of the fuse. A blasting cap is very *sensitive* and will not stand rough treatment. The end of the fuse should go into the end of the blasting cap snugly; it should touch the charge in the blasting cap, but it should not be twisted into place.



Use care in taking cap from box

If the fuse is too thick to fit easily into the cap, take a piece of wood and with it roll the fuse on a hard, smooth surface, to reduce the fuse to the size desired.

Crimping the Blasting Cap

Exercise care in placing cap on fuse

Use nothing but cap crimper for crimping cap on fuse

When the end of the fuse is in place within the blasting cap then the sides of the latter should be squeezed down tightly (crimped) upon the fuse. THERE IS ONLY ONE WAY TO DO THIS RIGHT. Use a cap crimper. Do not use the teeth or a knife to make the crimp. The cap crimper is made for this purpose. You should always have one on hand.

Priming the Cartridge

First Method

Great care should be exercised in attaching the cap and fuse to the cartridge. Proceed as follows:

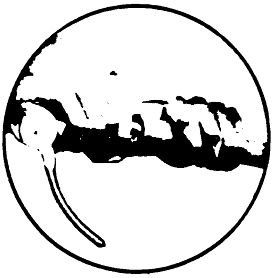


Fig. 1

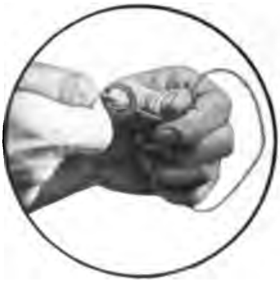


Fig. 2

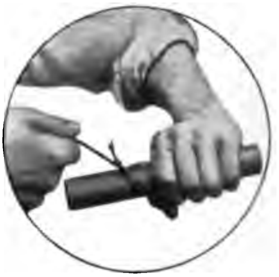


Fig. 3

1. With the handle of a cap crimper, or a piece of wood shaped something like a sharpened pencil, punch a hole 2 inches deep in the end of the cartridge. Direct the hole as nearly as you can down the center of the cartridge.

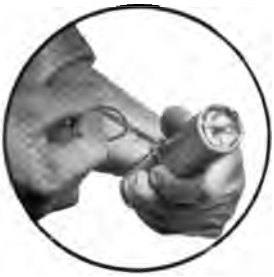


Fig 4

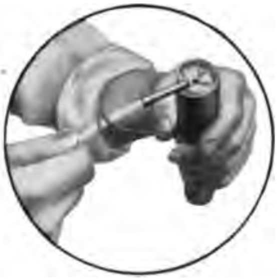


Fig. 5

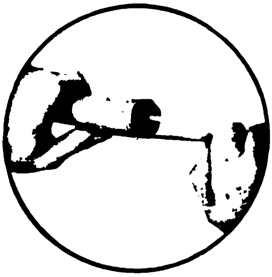


Fig. 6

2. Tie together the ends of a short piece of strong, soft string.
3. Make a clove hitch with the string. Put the hitch over the cartridge.
4. Make another clove hitch, using the free end of the string.
5. Through this hitch place the fuse and blasting cap and lodge the latter in the hole made in the end of the cartridge.
6. Slide the string forming the second clove hitch up along the fuse, thus tightening the hitch, until the fuse is bent. (See the illustration.)
7. Pull the string tight all around.

Do not make the hole in the cartridge any larger or any deeper than is needed to receive the blasting cap. Don't imbed the fuse in the cartridge or lace the fuse through the cartridge, as the fuse may spit fire through the side while burning and set fire to the charge.

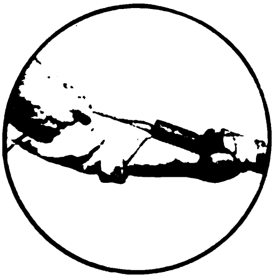
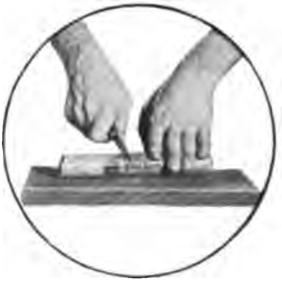


Fig. 7


The proper way to cut a stick of powder—roll the powder under the knife

By this method, the fuse and blasting cap are held firmly in the correct position. They will not be pulled out of this position when the charge is tamped. When water is present, cover the cap, also the dynamite where the cap enters, with Kapseal.

Second Method

Unfold the paper at the end of the cartridge. Punch the hole just as in the first method. Put the crimped blasting cap in the hole. Fold the paper around the fuse, and, using strong, soft string, tie the paper securely to the fuse. This method holds the fuse and blasting cap in the correct position. However, when the cartridge is being lowered into the hole and when the hole is being tamped, there is some danger of the paper becoming loose where it is tied about the fuse. Therefore, the first method is preferred.

TO EXPLODE WITH MINERS' SQUIB

The miners' squib is used only with blasting powder. With the squib a "blasting barrel" or a "miners' needle" must be used.

A blasting barrel is a piece of ¼ inch gas pipe. One end of the pipe is imbedded in the open end of the last cartridge.

When this cartridge is put in place in the bore hole, the end of the barrel should extend outside of the hole a trifle. The tamping material is packed closely around the barrel until the hole is filled. The squib is put into the exposed end of the barrel with the slow match end of the squib sticking out.

The slow match of the squib is ignited, and burns back to the train of powder within the squib. The force of the flashing powder propels the squib like a sky-rocket, back into the hole and ignites the charge. After the blast the barrel should be recovered. It may be used several times.

The miners needle is a rod of metal, usually brass or copper-tipped, 5 to 8 feet long and ¼ inch in diameter. This is given a coating of soap. The point of the needle is pushed into a cartridge 2 or 3 inches. This cartridge is then loaded into the bore hole with the other end of the needle protruding. The tamping material is packed closely about the needle, until the hole is filled. The needle is then carefully pulled out. The result is a hole the diameter of the needle. The squib is next inserted into this hole with the slow match end sticking out. The squib ignites the charge, just as in the case of the blasting barrel. The hole left by the needle may cave in. Therefore, it is better to use the blasting barrel. Each of these methods has the same disadvantage as with safety fuse. It ignites the outer end instead of the center of the charge.

UNIV. OF CALIFORNIA

ELECTRICAL FIRING

Under many conditions it is of great advantage to fire by electricity. The chief reasons are these:

1. Two or more shots may be fired at the same time. In most cases a greater amount of material can be moved and broken more completely when the blasting is done electrically.

2. The firing can be done the exact moment desired.

3. The firing can be done from a distance. The operator can be entirely outside the zone of danger

4. Chances of *misfires* or *hang-fires* are minimized.

5. In wet work the results are more certain than with cap and fuse.

6. The risk of igniting gas or dust in underground work is reduced to a minimum.

7. The amount of objectionable smoke and fumes given off is lessened.

Priming the Cartridge

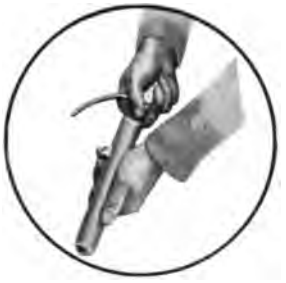


Fig. 1

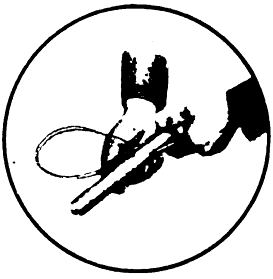


Fig. 2

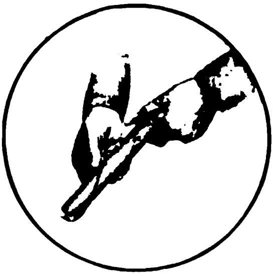


Fig. 3

1. Using the handle of a cap crimper, punch a hole in the end of the cartridge. Direct it diagonally so that the hole will come out through the side about 3 inches down.

2. Fold over the wires about 12 inches from the electric blasting cap to form a sharp bend. Then pass the doubled wires through the hole, and open the loop.

3. Pass the loop over the other end of the cartridge.

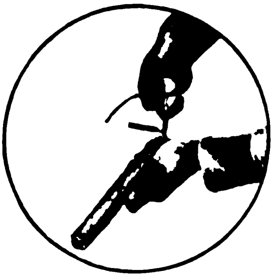


Fig. 4

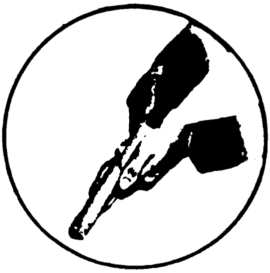


Fig. 5

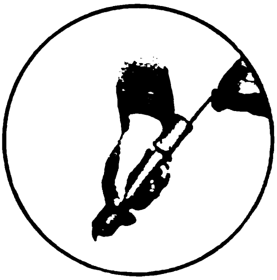


Fig. 6

4. Next punch another hole straight down into the cartridge beside the first one making it deep enough to receive the electric blasting cap.

5. Insert cap in this hole.

6. Take in the slack.

This arrangement prevents any strain on the wires where they enter the electric blasting cap.

Do not make half hitches with the wires around the cartridge. There is danger of breaking a wire, or injuring the insulation and causing a short circuit.

The method, sometimes followed, of putting the electric blasting cap in the side of the cartridge is not recommended. The electric blasting cap (No. 6, $1\frac{9}{16}$ inches long, or No. 8, 2 inches long) pushed into the side of cartridges, $\frac{7}{8}$ to $1\frac{1}{2}$ inches in diameter, may go through to the opposite side and *reduce* the force of detonation.

Priming for Delay Electric Blasting Caps and Delay Electric Igniters

Use the same methods that are recommended for priming a cartridge with an electric blasting cap or blasting cap. They must not be seated deeper than 6 inches in the primer cartridge as at least 2 inches of the explosive should be below the detonator. Particular care is necessary when tamping not to disturb the part of the delay electric blasting cap or delay electric detonator extending out of the cartridge.

To Explode with Electric Squib

The best way to ignite small charges of blasting powder is either by an electric blasting cap or an electric squib. Of the two devices, the electric squib costs less and is equally effective. The electric squib is to be used in a manner similar to that followed with an electric blasting cap.

If the blasting powder is used in bulk form, the electric squib should be placed in the hole when one-half of the charge has been loaded. Then the remainder of the charge should be loaded. This starts the explosion in the center of the charge. The electric squib permits the firing of one or more charges at the same time, as is the case with the electric blasting cap. Always remove the cork from the end of the squib before inserting in the powder.

Dynamite Primer for Blasting Powder

If a heavy charge of blasting powder is to be used, a dynamite primer is recommended. This primer should be a cartridge of dynamite into which has been inserted an electric blasting cap. The dynamite should be of strength of not less than 40%. The primer should be placed at the centre of the charge.

How to Operate Blasting Machines

Different styles to meet various conditions are sold by the Atlas Powder Company.

These machines are built substantially, but the user is cautioned to keep the various parts in proper working order. A machine should not be subjected to rough treatment, rain or even dampness, if one expects to get the best results. Blasting machines should not be kept in underground operations, unless stored in a dry place when not in use.

When operating a blasting machine it should rest on a level spot, otherwise in pushing down the rack bar it is apt to jam, producing weak current and possibly a misfire.

The power in Atlas No. 3 and U. S. Standard Blasting Machines is generated through the action of the rack bar. The bar should be lifted by the handle, to its full height. Then with all possible force, it should be pushed to its lowest point. It will be found that the bar moves more stiffly as it nears the bottom. This is due to the resistance from the action within the machine. The resistance increases with the advance of the rack bar. Sufficient force should be applied to keep the bar moving at undiminished speed from top to bottom.

The use of the Atlas Blaster (made in three sizes) is explained under its own heading in the list of Blasting Supplies, Chap. IV, pages 83 and 84.

Use of Atlas Galvanometer and Rheostat

The galvanometer and rheostat are important factors in all electrical blasting.

The galvanometer is used to test electric blasting caps; and also to test the line for breaks or short circuits.

The rheostat is used to determine the capacity of a blasting machine and for checking the resistance reading of the galvanometer. It will be seen, therefore, that these two instruments are most valuable in guarding against misfires.

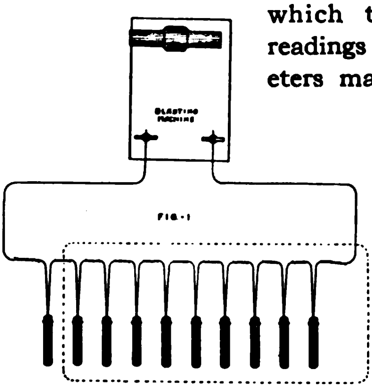
The galvanometer contains a chloride of silver dry cell battery. This supplies a very weak current. The indicator, moving across the face of a graduated scale or dial, shows the amount of resistance in the electric circuit to which the galvanometer is connected. A case, made of metal and hard rubber, encloses the cell and resistance coil. This fits into a leather case which can be easily carried by means of a strap attached to it. The two contact posts are conveniently located on the top of the metal case.

Connections can be made with the contact posts of the rheostat so that it will give the same amount of resistance to the electric current from a blasting machine that would be given by a pre-determined number of electric blasting caps connected together in single series for a blasting operation. It will give a total resistance equal to 150 electric blasting caps having either 30-foot copper wires or 6-foot iron wires. These lengths of wires are taken as standards. If longer wires are used, the blasting machine will not fire as many as its rated number of electric blasting caps.

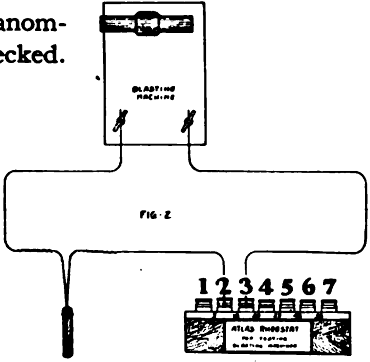
The following table shows the resistance equivalent in electric blasting caps indicated for various ways in which the 7 posts of the rheostat may be paired:

Between posts	Resistance equal to	Between posts	Resistance equal to
1 and 2	5 Electric Blasting Caps	1 and 5	60 Electric Blasting Caps
2 " 3	10 " " "	4 " 6	65 " " "
1 " 3	15 " " "	3 " 6	85 " " "
3 " 4	20 " " "	5 " 7	90 " " "
4 " 5	25 " " "	2 " 6	95 " " "
2 " 4	30 " " "	1 " 6	100 " " "
1 " 4	35 " " "	4 " 7	115 " " "
5 " 6	40 " " "	3 " 7	135 " " "
3 " 5	45 " " "	2 " 7	145 " " "
6 " 7	50 " " "	1 " 7	150 " " "
2 " 5	55 " " "		

The purpose of the rheostat is to provide an inexpensive means of ascertaining the capacity of a blasting machine and a standard by which the resistance readings of galvanometers may be checked.



FIG·1



FIG·2

If we have a blasting machine rated as capable of firing, say ten electric blasting caps, there are two ways in which its ability to do this may be proved: First, a circuit of ten electric blasting caps (Figure 1) can be connected and the attempt made to fire them all, or second, a circuit can be prepared eliminating nine of the ten electric blasting caps and replacing them with an equivalent resistance (Figure 2.)

If, under these circumstances, the single electric blasting cap can be fired, it is presumptive evidence that the blasting machine is capable of firing ten electric blasting caps when connected as shown in Figure 1.

Every electric blasting cap, electric igniter and electric squib, should be tested before and after loading the holes. After loading, the entire circuit should be tested. To do this, two short pieces of leading wire should be connected with the two posts of the rheostat that indicate a resistance equivalent to that of the blasting circuit. The opposite ends of these wires should be pressed upon the contact posts of the galvanometer. The position of the indicator on the dial should be noted. Next the outer ends of the two leading wires in the blasting circuit should be well scraped and pressed upon the contact posts of the galvanometer. The position of the indicator on the dial should be approximately the same as before. If it is not, the cause may be a short circuit or defective wiring. In that case, the circuit should be examined, section by section.

To test the galvanometer, lay a short piece of copper wire across the contact posts. Then note the position of the indicator. If the dry cell is at its full strength, the indicator should move entirely across the face of the dial. If the dry cell is nearly, or quite exhausted, the indicator will move a very little or not at all, and a new one must be secured before the galvanometer readings will be reliable.

CHAPTER VI

Tests—Quality

GREAT care and skill are used in making Atlas Explosives. To make explosives safer when properly handled has been the aim. This has been done. Now something further is sought—to make certain that products are kept up to the high standard. The perfect explosive must be perfect in action. It must always "run true to form." To achieve this, perfect material and workmanship are needed. The machinery also must be of the best. The Atlas Powder Company employs these three essentials: The best material, the best workmanship and the best machinery.

To get a perfect product is one thing. To continue getting it year after year is quite another matter. This latter result is achieved by eternal vigilance which, after all, is the price of success.

MATERIAL

The raw material for the making of explosives is supplied in large quantities to the Company's mills. This makes possible the finest grading. The best in quality is always on hand. There are no delays caused by waiting for raw materials. The quantity is there to keep the quality always up to the highest standard.

WORKMANSHIP

Every plant is in charge of a man of proved ability. He knows the work from the bottom up. The workmen are highly skilled and always may be depended upon to do their share in maintaining the quality standard.

MACHINERY

The Atlas Powder Company uses the most modern machinery. Every device known for aiding the maintenance of precision in every process is employed. Nothing is allowed to get out of order.

ETERNAL VIGILANCE

An outsider cannot imagine how closely the Atlas product is watched and examined. The most careful tests are made throughout the manufacturing process, both at the plants and again at the Atlas general laboratories. The weighing machines and testing devices are extremely delicate and kept in correct adjustment and in perfect order.

The Atlas Powder Company has a staff of experts supervising the manufacture of Atlas Explosives. Both raw materials and the finished product are tested by them. These experts also devote a great deal of time to devising new methods, new forms of machinery, new ways of making use of the science of chemistry in the industry. By such means new forms of explosives for special kinds of work have been discovered. Several of these are described in Chapter IV on "Explosives and Blasting Supplies." Science is the guide of the explosive industry.

When the explosives are packed the same vigilance is exercised. Each case is packed separately. It is filled while on the scales. If it is a 25-pound case, that amount goes in—exactly. If it is a 50-pound case, that amount goes in—exactly.

All cases are tared to their exact weight. Tare beam is fixed to register this allowance

CHAPTER VII

Service

TO have some one who really KNOWS standing at your elbow when you are figuring out the best way to make a blast, is something to be thankful for.

In any particular piece of work, questions of judgment often arise as to the kind or grade of explosive best suited to that particular work; as to the position and depth of the holes to be drilled; the strength of the charge; the priming and the tamping needed for the charge; etc. There are men representing the Atlas Powder Company, who stand ready to deal with these questions. These men are at your service.

THE ATLAS POWDER COMPANY'S SERVICE DIVISION WILL SEND A MAN TO ANSWER YOUR QUESTIONS

Many users of the Atlas Explosives and Blasting Supplies have had the help of this Division. In many instances the Division has suggested ways of doing the work with less cost.

It stands to reason, that the extensive experience of the Division in handling explosives and blasting supplies should add materially to the value of its recommendations. Furthermore, the files in the Division office contain records showing actual results in thousands of blasting operations. These records are authentic and can be made of value to you. They may point to a piece of work so very nearly like yours that they will be of great service to you. They may save you from inconvenience. They may save time. They may save money for you. Therefore, do not hesitate to write to the Atlas Service Division when you have a problem to solve.

By consulting the Service Division of this Company, certain very practical points about the economical use of explosives and blasting supplies may be gained—points that will help in reducing cost.

A HANDBOOK ON AGRICULTURAL BLASTING

The book, "Better Farming with Atlas Farm Powder," contains a great deal of information on every form of Agricultural Blasting. A copy of this valuable book will be sent to anyone writing for it. Do not forget, however, that the Atlas Service Division is always ready to take up and consider any particular condition in which you wish to employ explosives.

When you write about your problems, address the Atlas Powder Company Service Division, Wilmington, Delaware.

What Explosives and Blasting Supplies to Use for Agricultural Work

1. USE Atlas Farm Powder, Atlas Non-freezing Farm Powder or Atlas L. F. Extra 40% Dynamite for dry ditch blasting.
2. USE Atlas L. F. Nitroglycerin Dynamite 50% or 60% for wet ditch blasting by transmitted method of firing.
3. USE Atlas Farm Powder, Atlas Non-freezing Farm Powder, Atlas Stumping Special 2 L. F. or Atlas L. F. Extra 40% Dynamite for stump blasting.
4. USE "Crescent" or "Charter Oak" Fuse for wet work.
5. USE "Triple Tape" Fuse for work in water.
6. USE "Beaver" Fuse for all other agricultural work.

CHAPTER VIII

Handling, Storage, Delivery, Etc.

SOMETHING was said in the chapter on "TESTS—QUALITY" about the manner in which Atlas Explosives are made. The height of human skill and vigilance is reached in their production. In the handling, storage, delivery, etc., the user should have in mind these facts:

In the first place, explosives are not treacherous foes lurking within their coverings to smash one to bits. They are friends. They wait to do one's bidding. An explosive is like a spirited horse. Treat it with respect and it will serve you well.

An explosive will not stand too much heat. A fire of any kind makes heat. A spark from a locomotive, or anything burning, will make heat. A spark is sometimes caused by striking iron against iron, (or other metal or stone) letting a box or other object fall upon another object or upon the floor, will cause a concussion. If there is any form of explosive near at the time, there may be trouble. Friction is sure to cause heat, even if in a very small amount. An explosive will stand considerable heat caused by friction, shock or jar due to careless handling, but at a certain point it will rebel. Like any other friend it expects from you—the user—a fair degree of consideration. That is all.

If an explosive is frozen, handle it gently and thaw it strictly in accordance with the makers' instructions. In the leaflet referred to below, you will find several different methods of thawing recommended. Remember that your friend, the explosive, is suffering from too much cold and remember, also, that it does not behave well with too much heat. All forms of correct thawing depend upon heat of a moderate temperature. Therefore, the heat used must be of a known degree and must never be allowed to get beyond control.

Some explosives are made so that water does not affect them. They are described in Chapter IV. As a rule, however, explosives of every kind should be protected not only from water but should be kept away from wet or damp places. They should, of course, be protected from rain. This must be kept in mind when an explosive is being moved from place to place.

RULES AND REGULATIONS FOR SHIPPING, STORING OR HANDLING EXPLOSIVES

Any one having anything to do with the storage, handling, shipment or use of explosives should procure and familiarize himself with the most approved safety rules on these subjects. Safety rules, issued by the Institute of Makers of Explosives can be obtained from the Atlas Powder Company upon application.

Wherever there are laws or ordinances governing these factors, copies of the regulations should be procured and adhered to under all circumstances.

Rail and boat transportation of explosives is regulated by the Interstate Commerce Commission. Complete regulations have been published in book form, copies of which may be obtained from the Bureau for the Safe Transportation of Explosives, 30 Vesey St., New York City, and the rulings must be complied with by all persons shipping explosives.

Storing Explosives—There are right and wrong ways of storing explosives. You should ascertain the proper way to build a storage house (called a magazine) for dynamite and all forms of high explosives; for blasting powder and for black and smokeless sporting powders; for blasting caps, electric blasting caps, and other blasting supplies. Get accurate information on this important subject. Whenever explosives or blasting supplies are removed from magazine, move the oldest stock first.

THE ATLAS POWDER COMPANY WILL GLADLY SEND TO ANYONE ASKING FOR THEM ANY OF THE FOLLOWING NAMED BOOKLETS—WITHOUT CHARGE

1. Standard Storage Magazines—containing full information, how to build a storage house for explosives;
2. How to thaw explosives safely;
3. Institute of Makers of Explosives Safety First Rules for Shipping, Storing and Handling Explosives.
4. American Table of Distances for Location of Magazines.

CHAPTER IX

Don'ts

DON'T forget the nature of explosives. Also, remember that with proper care they can be handled with comparative safety.

DON'T smoke while you are handling explosives, and don't handle explosives near an open light.

DON'T shoot into explosives with a rifle or pistol either in or out of magazine.

DON'T leave explosives in a field or any place where stock can get at them. Cattle like the taste of soda and saltpetre in explosives, but the other ingredients probably would make them sick or kill them.

DON'T handle or store explosives in or near a residence.

DON'T leave explosives in a wet or damp place. They should be kept in a suitable dry place, under lock and key, where children or irresponsible persons cannot get at them.

DON'T explode a charge to chamber a bore hole and then immediately reload that hole as it will be hot and the second charge may explode prematurely.

DON'T do tamping with iron or steel bars or tools. Use only a wooden tamping stick with no metal parts.

DON'T use a miners needle of iron or steel when firing by means of squibs; use one of copper or brass.

DON'T *force* a primer into a bore hole.

DON'T explode a charge before every one is well beyond the danger zone and protected from flying débris. Protect your supply of explosives also from danger from this source.

DON'T hurry in seeking an explanation for the failure of a charge to explode.

DON'T drill, bore or pick out a charge which has failed to explode. Drill and charge another bore hole at least two feet from the one that failed to fire.

DON'T use frozen or chilled high explosives. Those other than the low freezing or non-freezing grades often chill at a temperature between 45° F. and 50° F.

DON'T use any arrangement for thawing Atlas Explosives other than one of those recommended by Atlas Powder Company.

DON'T thaw high explosives on heated stoves, rocks, bricks or metal, or in an oven, and don't thaw high explosives in front of, near or over a steam boiler or fire of any kind.

DON'T take high explosives into or near a blacksmith shop, or near a forge on open work.

DON'T put high explosives on shelves or anything else directly over steam or hot water pipes or other heated metal surfaces.

DON'T cut or break a high explosive cartridge while it is frozen and don't rub a cartridge of high explosives in the hands to complete thawing.

DON'T heat a thawing house with pipes containing steam under pressure.

DON'T place a hot water thawer over a fire, and never put high explosives in hot water or allow them to come in contact with steam.

DON'T allow thawed high explosives to remain exposed to low temperatures, but use as soon as possible.

DON'T allow priming (the placing of a blasting cap or electric blasting cap in high explosives) to be done in a thawing house or magazine.

DON'T prime or connect charges for electric firing during the approach or progress of a thunder storm. If charges are already primed, keep everybody away until the storm is over.

DON'T drop or throw about kegs of blasting powder.

DON'T open kegs by cutting with a cold chisel or by driving a pick through them. Always open the bung or slide.

DON'T try to use wet blasting powder. If it is only damp, it may be dried by spreading it out in the hot sun on a dry day.

DON'T permit kegs containing blasting powder to remain open after having taken out the quantity needed for use.

DON'T carry blasting caps or electric blasting caps in your pocket.

DON'T tap or otherwise investigate a blasting cap or electric blasting cap.

DON'T try to withdraw the wires from an electric blasting cap.

DON'T attempt to take blasting caps from the box by inserting a wire nail or other sharp instrument.

DON'T fasten a blasting cap to the fuse with the teeth or by flattening it with a knife—use a cap crimper.

DON'T keep blasting caps, blasting machines or electric blasting caps in a damp place.

DON'T store or transport blasting caps or electric blasting caps with other explosives.

DON'T use the regular electric blasting caps in very wet work. For this purpose secure waterproof electric blasting caps.

DON'T operate blasting machines half-heartedly. They are built to be operated with full force. They must be kept clean and dry.

DON'T handle fuse carelessly in cold weather, for when cold it is stiff and breaks easily and should be warmed slightly before uncoiling.

DON'T store fuse in a hot place, as this may dry it out so that uncoiling will break it.

DON'T lace fuse through cartridges of high explosives. This practice frequently is responsible for the burning of the charge.

DON'T fail, when about to load a hole with blasting powder, to see if there is nearby a steam shovel, locomotive, or any other point from which a spark or cinder might be blown into the hole. If there is, either stop the loading and protect the powder until this danger is passed, or else screen the hole from the danger.

DON'T expect high explosives to do good work if you try to explode them with a detonator weaker than a No. 6.

DON'T use grease or thin oil for waterproofing fuse.

DON'T use a naked light near an open keg of powder, because when filling the bags or shells, the dust from the powder may communicate with any naked light and carry the flame into the main body of the powder; or a spark from the light may blow into the powder.

DON'T worry along with old, broken leading wire or connecting wire. Misfires are costly.

Index

	PAGE
Ammite	65
Atlas Offices and Plants	7
Bags, Tamping	92
Black and Smokeless Powder	70
Blasting Caps	73, 74
Blasting Caps, Electric	74, 75
Blasting Gelatin	57
Blasting Machines	83-89
Blasting Machine Repairs	88
Blasting Paper	92
Blasting Powders	68-70
Blasting Supplies	71-96
Blasting Supplies, How to Use	97-106
Blue Label Squibs	78
Cap Crimpers	81
Caps, Blasting	73, 74
Caps, Delay Electric Blasting	76, 77
Caps, Electric Blasting	74, 75
Caps, Waterproof Electric Blasting	75
Cells, Galvanometer	93, 104
Coalite—Permissible Explosives	60, 61
Comparative Densities of Explosives	52
Comparative Granulations of Blasting Powders	69, 70
Connecting Wire	82
Cordeau-Bickford	80
Crimpers, Cap	81
D. & B. Squibs	78
Delay Electric Blasting Caps	76, 77
Delay Electric Igniters	77
Density, Comparative	52
Detonators	72-80
"Don'ts"	113-115

PAGE
Dynamite, Extra 54
Dynamite, Extra Gelatin 56
Dynamite, Gelatin 56
Dynamite, Nitroglycerin 53

Electric Blasting Caps 74, 75
Electric Blasting Caps, Waterproof 75
Electric Squibs 79, 80
Explosives, Handling, Storing and Delivery of 111, 112
Explosives, How to Use 39
Explosive, Oil Well 58
Extra Dynamite 54
Extra Gelatin Dynamite 56

Farm Powder 66
Farm Powder, Non-freezing 67
Fireworks Powder 70
Fuse, Safety 71, 72

Galvanometers 93, 104
Gelatin, Blasting 57
Gelatin Dynamite 56

Handling, Storage and Delivery of Explosives 111, 112
High Explosives (Explosives of the Dynamite Class) 10-12
How to use Blasting Supplies 97-106
How to use Explosives 39-48

Igniters, Delay Electric 77

Kapseal 92
Kettles, Thawing 94

Leading Wire (Single and Duplex) 81
List of Atlas Explosives 49
List of Atlas Blasting Supplies 50
Low Powders 63, 64

Magazines, Steel and Iron 96
Miners Squibs 78

PAGE
Nitroglycerin Dynamite 53
Non-freezing Explosives (see Amonite) 65
Non-freezing Farm Powder 67

Oil Well Explosives 58

Packing, Methods of 51
Paper, Blasting 92
Plants, Location of Atlas 7
Permissible Explosives (Coalite) 60, 61
Powder, Blasting 68-70
Powder, Black and Smokeless 70
Powder, Farm 66
Powder, Non-freezing Farm 67
Powder, Fireworks 70
Powder, Squib 70
Powders, Low 63, 64
Powders, Quarry 64
Powell Squibs 78
Priming Cartridges 98-100

Quality Tests 107, 108
Quarry Powders 64

Red Cross Squibs 78
Repairs for Blasting Machines 88
Rheostats 93

Safety Fuse 71, 72
Service Division, Atlas 109, 110
Smokeless and Black Powder 70
Squib Powder 70
Squibs, Blue Label and Red Cross 78
Squibs, D. & B 78
Squibs, Electric 79, 80
Squibs, Miners 78
Squibs, Powell 78
Storage of Explosives 95, 96, 111, 112

PAGE
Stumping Special No. 2 67
Sureshot Shells 90, 91

Table of Densities 52
Tamping Bags 92
Tests—Quality 107, 108
Thawing Kettles 94

Waterproof Electric Blasting Caps 75
What Explosives are Used for 14-38

ODUCTS

PAGE
Nitroglycerin Dynamite . . . 53
Non-freezing Explosives see Amonite . . . 65
Non-freezing Farm Powder . . . 67

Oil Well Explosives . . . 58

Packing, Methods of . . . 51
Paper, Blasting . . . 92
Plants, Location of Atlas . . . 7
Permissible Explosives (Coalite) . . . 60, 61
Powder, Blasting . . . 68-70
Powder, Black and Smokeless . . . 70
Powder, Farm . . . 66
Powder, Non-freezing Farm . . . 67
Powder, Fireworks . . . 70
Powder, Squib . . . 70
Powders, Low . . . 63, 64
Powders, Quarry . . . 64
Powell Squibs . . . 78
Priming Cartridges . . . 98-100

Quality Tests . . . 107, 108
Quarry Powders . . . 64

Red Cross Squibs . . . 78
Repairs for Blasting Machines . . . 88
Rheostats . . . 93

Safety Fuse . . . 71, 72
Service Division, Atlas . . . 109, 110
Smokeless and Black Powder . . . 70
Squib Powder . . . 70
Squibs, Blue Label and Red Cross . . . 78
Squibs, D. & B . . . 78
Squibs, Electric . . . 79, 80
Squibs, Miners . . . 78
Squibs, Powell . . . 78
Storage of Explosives . . . 95, 96, 111, 112

PAGE
Stumping Special No. 2 67
Sureshot Shells 90, 91

Table of Densities 52
Tamping Bags 92
Tests—Quality 107, 108
Thawing Kettles 94

Waterproof Electric Blasting Caps 75
What Explosives are Used for 14-38

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